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COLORS OF THE STARS

THE JOURNAL of the British Astronomical Association for December has a Questions and Answers department. Of special interest is the following:

Q. Everyone knows that a white-hot solid is hotter than a red-hot one. But why do stars have the same range of colours, or at least the same designations of colours from white (A type) to red (M type), when even the so-called red stars are stated to be at a much higher temperature than a white-hot piece of metal in a terrestrial furnace?—THERMOSCOPE.

A. If one plots a graph showing the amount of energy emitted by a hot body at various wavelengths, it is found that there is one maximum point on the curve. As this curve is plotted for the body at successively higher temperatures, the wavelength at which the maximum occurs decreases—i.e. moves along the spectrum in the direction red to violet. It must be remembered that the range of wavelengths to be considered extends far on each side of the visible spectrum, and even for bodies at a temperature of 2000°C the maximum point on the curve lies far in the infra-red. If the maximum were very sharply defined, with the intensities falling away rapidly on each side of it, a body being heated would become visible first as a pure red colour only on reaching about 4000°C, and would then become successively pure orange, yellow, green, blue, indigo and violet, finally becoming invisible when the temperature had moved the maximum into the ultra-violet. But in fact the range of wavelengths emitted is very large, and the maximum not sharply defined. A body at about 700°C has its maximum far in the infra-red; there is sufficient light emitted in the visible red to affect the retina, but insufficient in the blue. The resulting colour is a fairly pure red. As the temperature is increased, sufficient light of all wavelengths is emitted to affect the retina, although light of the longer wavelengths at first predominates. As the temperature is further increased and the amount of energy at all wavelengths increases, the ratio of the amount of energy at the red end of the spectrum to that at the blue falls, until at the higher stellar temperatures there is a slight preponderance of the shorter wavelengths. The resulting sequence of colour is usually described in some such terms as 'dull red, cherry red, orange, yellow-white, white, bluish-white', etc.

The important point is that the definition of 'white' is very subjective, and largely a matter of contrast. The interior of a steel furnace (about 1500°C) looks 'white', but if compared with the pole of a carbon arc held near the molten steel, the comparative yellow colour of the cooler steel is readily apparent. We see the stars as relatively faint points of light on a black background, and the state of adaptation of the observer's eye, the condition of the atmosphere, and the altitude of the star, all affect a star's apparent colour. It is evident at a glance, however, that there is no star visible to the naked eye which is really **red** hot. The 'red' stars are so called only technically, because they are known to have a wavelength of maximum intensity at the red end of the spectrum. The naked eye can at most only discern their light to be appreciably yellower than the hotter F type stars, whilst the still hotter B and A type stars appear bluish-white. The effect of juxtaposition in making this colour contrast apparent is readily visible in many double stars.

In very cool stars a second effect makes the stars look more red than would be expected from the theoretical energy curve alone. Many of these stars have heavy absorption bands caused by molecules in their atmospheres, and these are so intense at the blue end of the spectrum that the blue light is almost totally removed. The best examples of these stars are the long period variables of spectral classes R and N, where the low temperature (about 2000°) and the molecular bands in the blue combine to produce the most intensely coloured stars known. None of these intrinsically faint stars is visible to the naked eye: the variable R Leporis, Hind's 'crimson star', is one of a few visible in a small instrument, and of all stars most nearly deserves the appellation 'intense blood red.'

It might be remarked in passing that whilst many double stars show well this contrast between bluish-white and yellowish-white stars of different temperatures, the rather fanciful and excessively minute descriptions of star colours to be found in the astronomy books of the last century, whilst honestly made, paid less regard to the false colour introduced by the object glass than was necessary. As an example of minute description of a star's colour, F. G. W. Struve's **olivacea subrubicunda** has probably never been surpassed!

—D. W. D.

SKY and TELESCOPE

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VOL. XII, No. 6 WHOLE NUMBER 138 — APRIL, 1953

CONTENTS

COVER: A photomicrograph of samples of meteoritic dust and other particles collected in Iowa by Warren J. Thomsen in the winter of 1951-1952. A human hair (diameter 40 microns) is shown in the upper left to give a scale of size. The clustering and stringing of the spheres is due to magnetism acquired from the gathering magnet and not fully lost during subsequent heating. The "glass" spheres were hand picked from other samples and dropped into the magnetic material for purposes of comparison. The spheres of both kinds are believed to be extraterrestrial in origin. No attempt has been made to identify the nonspherical material. State University of Iowa photograph. (See page 147.)

BACK COVER: NGC 4565, one of the largest and most beautiful of the edgewise spirals, with a dark absorbing lane in its equatorial plane, photographed with the 200-inch Hale reflector at Palomar Mountain. It is of type Sb, measuring about 15.0 by 1.1 minutes of arc, of integrated photographic magnitude 10.7. Herschel designated the galaxy as 24^5; it is located in Coma Berenices at $12^h\ 33^m.9$, +26° 16′ (1950 co-ordinates). South is at the right. Mount Wilson and Palomar Observatories photograph.

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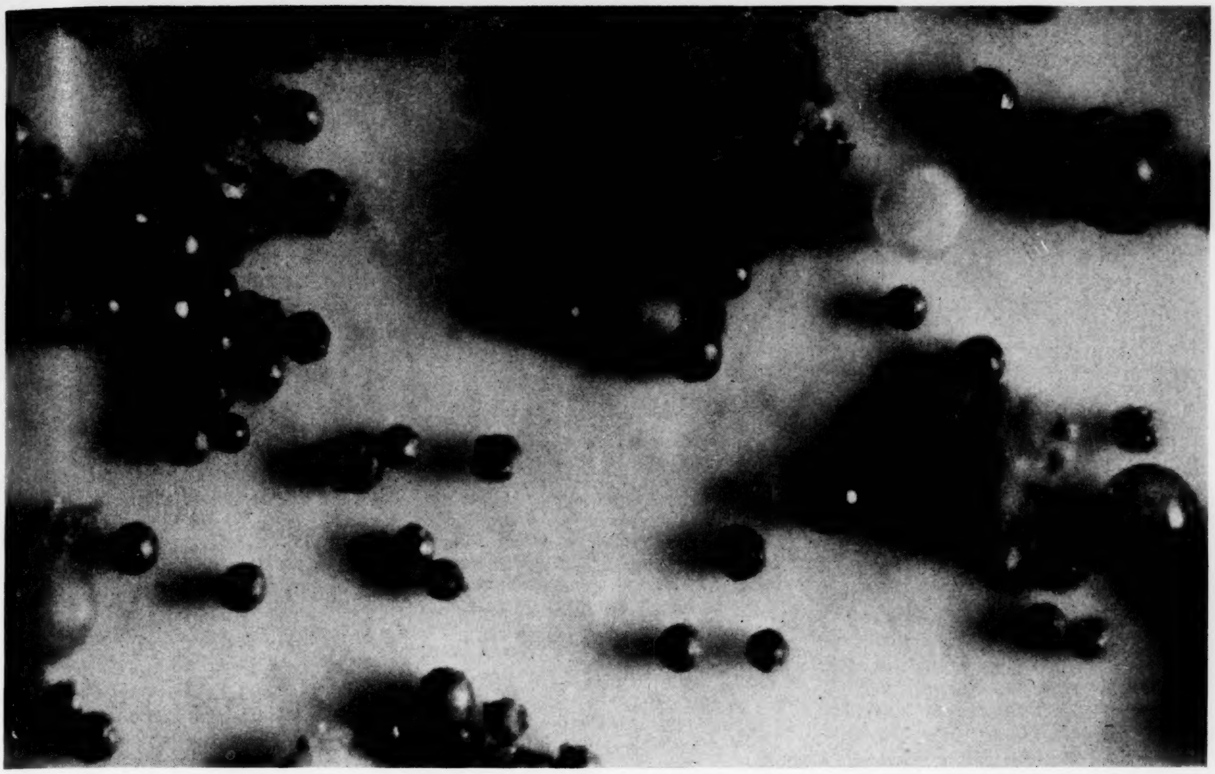


An enlarged section of the material shown on the front cover; some of the particles have different relative positions. Note the glasslike character of the sphere in the lower right, and the heavy clumping of the magnetized spheres at the left. State University of Iowa photograph.

The Annual Deposit of Meteoritic Dust*

BY WARREN J. THOMSEN, *Wisconsin State College, Whitewater, Wis.*

METEORITIC DUST, material of extraterrestrial origin, has been identified in two principal forms: spherical particles and irregular, angular particles. Proof of the origin from outside the earth for the spherical particles is based on several lines of evidence: chemical analysis; the fact that their formation cannot be attributed to any known natural terrestrial causes; the tendency to obtain higher counts of spherical particles after known meteor showers; and the occurrence of spherical particles at all times of the year in several widespread localities.

It is believed by many scientists that the spherical particles are formed from molten material swept from the surfaces of the solid bodies of meteors. The sizes of the spheres observed are of the proper order of magnitude to have been derived in this manner. It is also possible that very small meteors might form the spheres when fused by their friction with the atmosphere; they would not be large enough, however, to produce sufficient light to attract attention as meteors.

For the angular particles the proof is not so certain. A theory has been advanced by Buddhue[1] that the angular particles may be derived from interplanetary or interstellar dust which drifts into our atmosphere; such particles may be the micrometeorites of Whipple.[2] Angular particles should also be produced by the fragmentation and bursting of ordinary meteors.

Meteoritic dust has been collected in several different ways. Some of the earlier investigators found meteoritic particles in snow, in hailstones, and on drift ice. Spherules, believed to be of meteoric origin, have been found in deep-sea deposits of clay and mud. Magnetic particles have been collected by letting the rain water from a roof flow over and around magnets at the lower end of a downspout. Microscope slides, coated with glycerin or some similar material, have been used to capture particles which fall on them. Another method utilizes containers to collect everything that falls in them.

At Iowa City, the writer has employed three methods of collecting. A few shiny, black magnetic spheres were recovered in water from melted snow. By using an alnico magnet in a test tube, fairly large samples of magnetic material were gathered from the flat roofs of some of the university buildings. The spherical particles were concentrated by letting them roll off smooth, tilted surfaces. Gallon cans, lined with plastic bags and set out in the same manner one would set out a rain gauge, were used as collectors.

A spectroscopic analysis of the magnetic spheres obtained from rooftops showed the following elements to be present: iron, silicon, and magnesium. Watson[3] has listed the average composition of stony meteorites as follows: oxygen, 36.3 per cent; iron, 25.6; silicon, 18.0; magnesium, 14.2; other elements, less than 1.5 per cent each. A gravimetric check of our sample gave the approximate composition: SiO_2, 28 per cent, and Fe_2O_3, 72 per cent. Since the melting points of silicon and iron are fairly close to each other, we would expect droplets formed by the meteoric process to contain a mixture of the two

*The work reported here was done at the State University of Iowa and was supported in part by the Office of Naval Research.

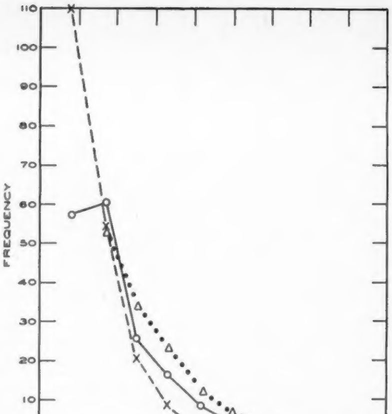
elements. Magnesium, with a very much lower melting point, should not occur in any great amount. The failure definitely to detect nickel was unexpected.

Notice that the three elements detected in the magnetic spheres are the three chief elements in meteorites. Artificial droplets of iron, such as weld splatter, are ruled out because they should not contain the high percentage of silicon. Natural terrestrial dust is ruled out by the spherical form and the failure to detect aluminum. The photographs here and on the front cover show the appearance of the material under the microscope. It is assumed that all of the spheres are of meteoritic origin.

To determine the rate of accumulation of meteoritic dust, several collectors (gallon cans lined with plastic) were set out in November, 1951, on a farm a few miles from Iowa City. Collections were also made in two rural areas in northwestern Iowa during February and March, 1952. Everything that accumulated in a collector was transferred, at monthly intervals, to a jar, and after a reasonable time had been allowed for settling most of the water could be poured off. A magnet in a test tube was used to transfer magnetic material onto a microscope slide. The water in the jar was evaporated, and the residue was examined under a microscope.

By means of a mechanical stage all spheres were counted, and their sizes were measured with a calibrated reticle in the eyepiece. The spheres were measured to the nearest unit on the reticle, which was equivalent to about 0.008 millimeter. Nonspherical material was not considered in this study. The nonmagnetic spheres were rather difficult to find since they were mixed with relatively large amounts of terrestrial dust. Of the total number of spheres, only about 20 per cent were nonmagnetic. Under the microscope, many of these looked like marbles, some clear and others with a milky appearance similar to that of pearls, as the pictures show. The distribution of the sizes of the magnetic spheres from three collecting periods is shown in the accompanying graph.

The rate of fall, derived from samples gathered during the period from November, 1951, to April, 1952, varied from 10^9 to 3.7×10^9 kilograms per year for the entire earth. The procedure to determine the annual rate of fall of magnetic, spherical, meteoritic dust for the earth was as follows: For each collecting period the total volume was calculated from the size and number of spheres. This volume was multiplied by the number of collecting periods in a year and by the number of collecting surfaces needed to cover the earth. Assuming the density of the magnetic spheres to be four grams per cubic centi-



A graph showing the size distribution of magnetic spheres for the following three periods: November 9 to December 10, 1951, triangles; January 10 to February 4, 1952, circles; and February 4 to March 11, 1952, crosses.

meter (they sank in a solution of bromoform, density 2.89), the total annual weight indicated was obtained for each sample.

The rate of fall which was adopted is 2.0×10^9 kilograms per year for the entire earth. This may be thought of as about 6,000 tons per day for the earth, or about 22 pounds per square mile per year. In terms of volume, a layer one micron deep is deposited every 1,000 years.

This figure, which does not include meteorites or nonspherical or nonmagnetic particles, is larger by a factor of about 1,000 than the figures published by Wylie[4] in 1935 or Watson[3] in 1941, as the contribution of meteors and meteorites. Millman,[5] in summarizing the work on the accretion of extraterrestrial material on the earth, indicates that visible meteors (including radio and telescopic) perhaps account for gains of up to 10 tons per day (which figure is of the same order as those given by Wylie and Watson), and that dust particles, not visible as meteors, contribute as much as 10,000 tons per day. This figure is based on the density of dust in space as determined by van de Hulst[6] in studying the zodiacal light.

The results of the investigation reported here should be considered as only preliminary. Collections for more than a few months are necessary, and they should be made at several different points on the earth. However, the figure of some 6,000 tons of dust which this study finds are gained by the earth each day supports van de Hulst's work on the density of dust in interplanetary space, and we are led to conclude that either the present physical theory of meteors leads to masses which are much too small or that only a very small fraction of interplanetary particles are large enough to cause visible meteors.

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RADIO "HAMS" CONTACT MOON

Amateur radio operators have succeeded in bouncing a short-wave signal off the moon and making visual recordings of the returning echoes. Late in January this feat was accomplished by Ross Bateman, W4AO, Falls Church, Va., and William Smith, W3GKP, Spencerville Md., according to an announcement by the American Radio Relay League, West Hartford, Conn.

Although a moon echo has been obtained before — in 1946 by the U. S. Army Signal Corps, and in late 1951 by the Collins Radio Company — this is the first time with amateur power and amateur techniques. Bateman and Smith used about 650 watts of power; the military and commercial attempts employed many thousands of watts.

On July 15, 1950, the two amateurs obtained one solitary moon echo, and since then they have made dozens of unsuccessful attempts. Finally, a new "stacked rhombic" antenna was constructed. Because of its bulk, this antenna is permanently installed in a specific orientation, and the radio hams must wait for the particular times each month when the moon reaches the right position for their experiment.

An associate in the work, Ted Tuckerman, W3LZD, of Dunmore, Pa., constructed elaborate apparatus in an attempt to receive signals from W4AO via the moon. On January 23, 1953, a series of weak echoes was picked up in Dunmore, and on January 27th a whole series of echoes was recorded at W4AO itself.

The March issue of QST, published by the ARRL, contains a full report of these experiments; subsequent articles in that magazine will cover technical details.

AAVSO MICHIGAN MEETING

The spring meeting of the American Association of Variable Star Observers will be held May 22-23, at the University of Michigan Observatory in Ann Arbor, by invitation of Dr. Leo Goldberg. A public lecture Friday evening will precede sessions for papers and the business meeting on Saturday.

American Astronomers Report

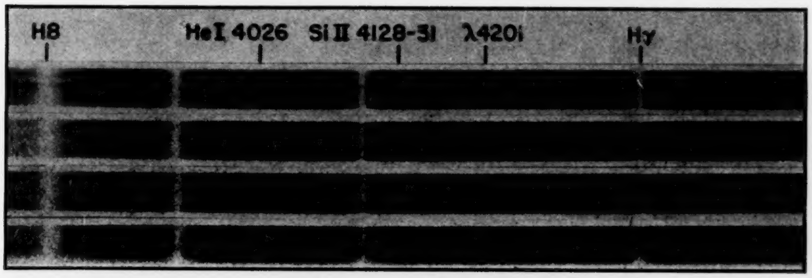
Here are highlights of some papers presented at the 88th meeting of the American Astronomical Society at Amherst, Mass., in December. Complete abstracts will appear in the Astronomical Journal.

A Spectrum Variable

About 15 or 20 naked-eye stars of type *A* are known to show absorption lines of variable strength. These spectrum variables do not change in brightness by more than a tenth of a magnitude, but the spectroscopic changes are often very pronounced. In 10 of the spectrum variables, the variations of the line strengths have been found to be regular, the periods ranging from half a day to 20 days.

Dr. Armin J. Deutsch, of Mount Wilson and Palomar Observatories, had reported at Rome that among these 10 spectrum variables the line widths are inversely proportional to the length of period except in the case of one star. With this one exception, the profiles of the lines in each spectrum are just what would be given by the rotation, with the period of spectrum variation, of a main-sequence star of type *A0*, provided the star is assumed to be viewed in or near the equatorial plane.

The exceptional star was 56 Arietis, in which the lines are three times too wide for the published period of 2.5 days. Since the period determination was a weak one, it was predicted that it was incorrect, and that the true period would be about half a day. In other words, the Doppler effect at the star's equator should be large and produce the great widening of its spectral lines.



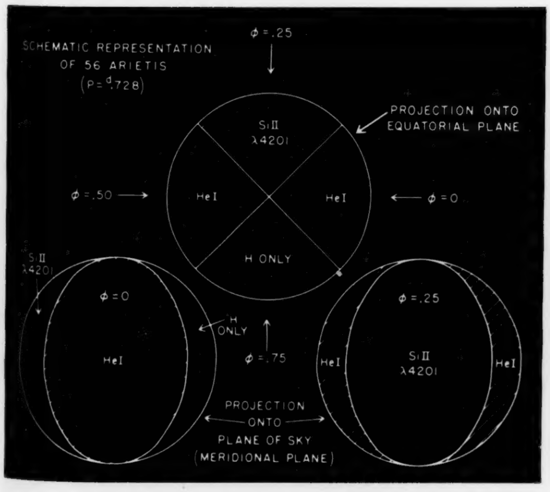
The sequence of changes in the spectrum of 56 Arietis, on which is based the representation below. Mount Wilson and Palomar Observatories photographs.

In his paper presented at Amherst, Dr. Deutsch stated that he had now verified this prediction. The true period of 56 Arietis is only 0.728 day, which conforms with the line widths. The spectrum variation is more complex than heretofore found, however, and the variable lines show large Doppler shifts.

Careful examination of the accompanying spectra shows the complex variations that probably account for the previously incorrect determination of the period. In the first spectrum are seen, in addition to the hydrogen Balmer lines, 4026 of neutral helium, 4128-31 of ionized silicon, and an unidentified line at 4201 angstroms. The Balmer lines are probably invariable, but in the second spectrum the SiII lines are greatly weakened, and the others have disappeared. In the third spectrum, the silicon lines and 4201 are again strong, but helium is weak or absent. And in the fourth spectrum, helium is strong while silicon and 4201 are weak.

Dr. Deutsch found that the helium lines exhibit two complete intensity cycles during one 0.7-day cycle of the silicon lines. His hypothesis is that the intensity variations are produced simply by the axial rotation of a spectroscopically "spotted" star viewed in the equatorial plane. Corresponding to its period, and to a radius of about 1.9 times that of the sun, 56 Arietis must have a rotational velocity of about 130 kilometers per second at the equator. As one of the spectroscopic patches is carried around the approaching limb of the star, the corresponding variable line should therefore show a Doppler shift of about two angstroms to the violet. An equal shift to the red should occur after maximum strength, at the receding limb. These shifts have been observed for all three variable lines, and they are of the expected magnitude and sign.

Finally, Dr. Deutsch has very tentatively constructed a crude schematic "spectroscopic map" of the atmosphere of 56 Arietis. As shown here, four distinct areas are indicated, roughly bounded by meridians 90 degrees apart. The lower two sketches show the star as we see it against the sky, the upper as it would appear if seen from above one of its poles. The phase of the rotation is ϕ. At phases 0 and .50, the "helium areas" dominate the stellar disk as we see it; at phase .25, the "silicon area" dominates the visible disk; and at phase .75 the normal "hydrogen only" area dominates it.



The hypothetical appearance of the star 56 Arietis, as seen from above one of its poles, and as seen from points in its equatorial plane 90 degrees apart.

Dr. Deutsch pointed out that this model is strictly *ad hoc,* the actual physical situation being highly obscure. Nevertheless, it does seem to be verified by his having found the helium line to be faintly double, with its components separated by nearly five angstroms, at phase .76. This is precisely at the middle of one helium minimum, and just when the helium at one limb would be most rapidly approaching while that at the other limb would be most rapidly receding. This situation should also probably hold at phase .25, during the silicon maximum.

Origin of Protogalaxies

Dr. George Gamow, of George Washington University, has computed the probable masses of the collections of matter from which the galaxies were formed when the universe was about 1/50 its present age. He pointed out that, according to relativistic theory of an expanding universe filled by a mixture of matter and radiation, there should first

have been a period in which the mass-density of radiation was much higher than the density of matter, but thereafter the situation became reversed.

The epoch at which the predominantly radiation universe gave place to the predominantly matter universe was about 70 million years after the expansion began. At that time, the temperature of space was 320° absolute, and the density of matter (as well as of the radiation) was about 10^{-25} grams per cubic centimeter.

As soon as matter became more important than radiation in the gravitational balance of the universe, previously homogeneous masses were bound to break up into individual gas clouds (which Dr. Gamow calls protogalaxies), the size and mass of each being determined by a well-known formula by Jeans. Substituting into this formula the above values of temperature and density gives for the minimum mass of a protogalaxy 50 million solar masses.

This figure is lower than the observed mean mass of galaxies by a factor of about 10 so that, in order to get complete agreement, it must be assumed that the primordial gas was in a state of turbulent motion with the Mach number 4. The assumption of supersonic turbulence in primordial gas is also necessary to understand the comparatively short time which was necessary for the condensation process.

Electric Spectrophotometry

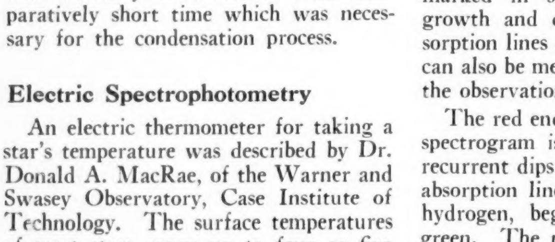
An electric thermometer for taking a star's temperature was described by Dr. Donald A. MacRae, of the Warner and Swasey Observatory, Case Institute of Technology. The surface temperatures of most stars range up to four or five times that of the sun, which is close to 6,000° centigrade. By combining a photoelectric cell and the objective prisms of the Schmidt telescope, small differences of temperature of the order of two per cent can readily be detected.

A hotter star will have a greater light intensity in the violet and a smaller intensity in the red when compared to a cooler star of the same apparent magnitude. This corresponds to the well-known fact that hot stars have a bluish hue while cool stars like the sun are yellowish. The photoelectric cell, recently put to widespread use in astronomical problems of light measurement, makes it possible to measure these differences of intensity with great accuracy directly from the spectrum of each star.

Previously, the photoelectric colors of stars have been studied by the use of broad-band light filters. The present method is more advantageous because the range of wave length admitted to the photocell at one time is much smaller, the part of the spectrum measured is accurately defined, and the heavy absorption lines which block off the star's continuous radiation can be avoided. The older methods of scanning photographic spectra in a similar manner also had these advantages, but the observations were tedious, only the brightest stars were generally accessible, and a single spectrogram was of low precision. The new instrumental combination can reach the 7th magnitude without serious loss of accuracy or telescope time. About five minutes are required for the tracing of one star's spectrum, with a result like that shown here for Vega.

Dr. MacRae showed how slight anomalies in the spectral distribution of a star's light intensity could be detected and how the color temperatures could be compared with temperatures found by other methods. The reddening of starlight by interstellar dust is clearly marked in some distant stars. The growth and decay of the stronger absorption lines along the spectral sequence can also be measured quantitatively from the observational data.

The red end of the Vega photoelectric spectrogram is toward the right. The recurrent dips in intensity are the strong absorption lines of the Balmer series of hydrogen, beginning with Hβ in the green. The numbers along the bottom are wave lengths in angstrom units. The horizontal tracing gives the measured intensity of the sky background; the height of the trace above this reading is directly proportional to the light intensity in the star's spectrum. The intensity falls rather abruptly in the red because the photomultiplier tube ceases to be sensitive to radiation much beyond 6000 angstroms. The intensity falls slowly toward the blue because the analyzing slit admits a smaller range of wave lengths as it proceeds in this direction, on account of the increasing dispersion of the prism.



A tracing of a spectrogram of Vega obtained with the 6-degree objective prisms and the photoelectric photometer attached to the Schmidt telescope of the Case Institute of Technology.

Yellow Coronal Line and Solar Flares

At the High Altitude Observatory, Frederick P. Dolder and Dr. Walter O. Roberts have correlated observations of the yellow coronal line (at 5694 angstroms) in the sun's outer atmosphere with solar flares and prominences. A list of all solar flares published in the IAU Quarterly Bulletin of Solar Activity for 1946 through 1950, when treated by simple statistical procedures, reveals an unmistakable degree of association between 91 flares and 43 instances of occurrence in this period of the yellow coronal line, as observed at Climax, Colo., and Sacramento Peak, N. M. Thirteen coincidences were involved; the probability for a number of chance coincidences equal to or greater than the observed number is less than 2/100,000.

Additional evidence exists associating certain prominences and the yellow coronal line. These prominences have more marked tendencies toward downward motion and toward apparent inflow of material from "space" than do prominences in general. They show more tendency to break into scattered knots, and less tendency to form large stable masses than do prominences chosen at random.

Magellanic Cloud Constellations

Constellations of blue stars in the Large Magellanic Cloud have been found to resemble the blue star aggregations of Orion, Scorpius, and Centaurus in our own galaxy, by Virginia McK. Nail and Dr. Harlow Shapley, of Harvard Observatory. These configurations are the most extensive structural features of the cloud, except for its main axis or bar and the great nebulosity known as 30 Doradus.

Five such aggregations have been measured for brightness and color on photographs made at Harvard's Boyden station in South Africa, and are found to be from 800 to 1,500 light-years in extent. On the average, these Magellanic constellations are each composed of a score of supergiant blue stars, with a few supergiant red stars among them.

Distant Galaxy Colors

Galaxies are generally of two kinds: elliptical and spiral. In 1947, Drs. Joel Stebbins and A. E. Whitford, then both of the University of Wisconsin, used photoelectric apparatus and the 100-inch Mount Wilson reflector to measure the colors of very distant galaxies. They reported an excessive reddening in the distant ellipticals, over and above the red shift normally to be expected by the Doppler effect of the expanding universe (see *Sky and Telescope,* March, 1948, page 123).

Now Dr. Whitford has made addi-

(Continued on page 155)

Astronomy from the Space Station*

By Fred L. Whipple, *Harvard College Observatory*

My DISCUSSION will be limited to the purely astronomical problems that will face the astronomer when he begins an observational program from an observatory located above the earth's atmosphere. I am going to omit intentionally the exceedingly important observations of the earth, particularly those meteorological and geophysical in character.

The astronomer must first design and locate an observatory that can be operated under the extremely unusual conditions in empty space. There are some very interesting problems concerning the simple matter of locating it with respect to the satellite station. The only really practical location is in the precise orbit of the satellite vehicle, ahead or behind; otherwise an oscillation normal to the orbital plane will occur in each revolution as well as a drift motion away from the satellite vehicle. In 24 hours the drift is nearly 40 times the distance toward or away from the earth with respect to the station orbit. The observatory could be placed in such a fashion that it would oscillate near the station, without being attached to it. This solution to the problem, however, is not a desirable one, since the station might come within the line of sight of the telescope too frequently. The astronomer would really wish to have the observatory at a greater distance from the earth than 1,075 miles, because of the large solid angle of the earth as seen from the orbit.

A number of technological problems with regard to the operation of the instrument must be considered and solved. Coating the mirror with a metal reflecting surface, however, will be the easiest of all — because of the complete vacuum in space. Furthermore, much electronic equipment will operate without the complication of vacuum seals, which constitute a considerable problem of electronic design and construction in a gaseous medium like our atmosphere. Various problems, such as orienting the instrument, holding its position accurately, and so forth, are of great interest in technological design. The question of shielding surfaces from rapid temperature changes produced by the sun and earth is of extreme importance. The observer will not be able to touch the telescope nor be within it, because of the precise directional control required for most problems. Hence all guiding will be by remote control, as will be the opening of shutters and other operations. The changing of films and plates can best be done by remote control, storage units being transferable to the telescope from the satellite station.

The spectroscopic techniques for the satellite station will be adaptations of laboratory vacuum methods now used for the far ultraviolet, X-rays, and gamma rays. Large regions in the radio spectrum will be opened up by the existence of the station above the ionosphere, and we may expect an extensive branch of radio astronomy to develop from the satellite vehicle. Furthermore, there exists the possibility of constructing huge antennas in space, so that the resolving power of radio astronomy may be greatly increased.

The useful electromagnetic spectrum extends at least over a power of 10^{20} in wave length or frequency. The eye sees scarcely a range of 2 in this 10^{20}, while the infrared and ultraviolet transmission of the atmosphere permits about a factor of 10. Recent innovations in radio astronomy open up a vast region of some 30,000 times from about one millimeter to 30 meters wave length. Extremely great progress is being made in these now accessible parts of the spectrum, but the most interesting parts, which lie in the ultraviolet, X-ray, and gamma-ray regions, are completely invisible from the earth's surface. Modern rocket explorations have made great strides in solar studies over these short wave lengths. The entire spectrum, from less than one angstrom unit in wave length (10^{-8} centimeter) up to radio-type waves comparable to the dimensions of the earth, can be observed from the satellite station.

The over-all astronomical fields of research to be covered will include solar problems, the planets and smaller bodies in the solar system, the stars, the galaxies, and the interstellar medium of gas and dust.

The solar research will undoubtedly be handled by small, specialized equipment of several varieties, each designed to attack a special problem of solar structure and activity. The present rocket program in the United States will give us preliminary information on many solar phenomena occurring in the far ultraviolet and X-ray region. We will be particularly interested in the direct measurement of corpuscular radiation from the sun, the far ultraviolet and X-ray spectra, and variations correlated with solar activity, such as of prominences, flares, and the corona. It is possible also that, from space, radar observations of passing corpuscular streams can be observed by reflection. Perhaps the question of cosmic ray sources in the sun will have been solved by the time the satellite observatory is ready, but certainly there will remain many studies of great interest bearing on this problem.

The planetary work will make use of the high resolving power of a large telescope with, say, a 100- or 200-inch mirror. In observing Mars, for example, a resolving power of approximately 10 miles should be possible with a 100-inch instrument. Of equal interest will be a study of the complete chemical composition of all planetary atmospheres, since the far ultraviolet will reveal the presence of molecules and atoms that do not absorb light in the photographic regions, or of others, such as water vapor, that are very opaque in our own atmosphere. Detailed observation of the composition of cometary atmospheres will be invaluable, not only with regard to the evolution of planets but concerning the possibility of life on them. Vital clues as to life processes are presented by atmospheric constituents.

In stellar astronomy, a huge endeavor involving spectroscopy in the far ultraviolet and X-ray region, and even in the gamma-ray region, will provide any large telescope, or even several of them, with programs for generations. Problems of stellar composition can be solved for all elements that are present even in exceedingly minute quantities, but I expect that the cream of these researches will have been skimmed by the great progress at present in the photographic spectrum. Nevertheless, the extent of the spectroscopic astrophysical field of endeavor is so great that innumerable new problems will arise and be solved in the early years of the satellite station. These concern not only the nature, composition, and evolution of stars, but the processes going on in their atmospheres, particularly loss of material, circulation of great clouds of material about double star systems, and possibly in some cases the accretion of matter from the interstellar medium.

If the nature of stellar evolution has not been thoroughly outlined before the satellite station is built, there is no question but that the space observatory will speed the rate of solution by a large factor. Furthermore, it will be possible to obtain clear insight into the nature of spectacular novae, supernovae, peculiar variable stars, giants, and white dwarfs.

A very important problem that will probably not be solved before the space observatory becomes a reality is that of the composition of the interstellar medium. Beyond the earth's atmosphere, it will be possible to determine the percentage of almost all trace elements in the interstellar medium; through the earth's atmosphere, even with radio astronomy techniques, only a very few of them can be isolated. The importance of this problem becomes apparent when we realize that many of the great gas and dust clouds of the Milky Way are stellar incubators in which new stars are, indeed, at the present time being born. We know that we observe many ancient stars, three billion years old or more, and at the same time a number of youngsters, perhaps only a hundred thousand years in age. There are already indications of fundamental differences in composition between these two groups of stars, young and old. Many questions of the greatest import in evolutionary theories concern the way in which the interstellar medium may have changed composition during the three or four billion years of universe history. Possibly changes have occurred by selective accumulation of stars from dust rather than from gases, or perhaps by the addition of heavier elements to the stellar medium by explosions of stars that have developed heavy elements within them, or perhaps by the continuous creation of matter, as Hoyle has suggested.

The observatory in space may well reveal the secrets of the origin of the universe itself. The most important problems for the space astronomer will probably be new ones, beyond the horizons of our science today.

*From a talk given at the Second Symposium on Space Travel at the Hayden Planetarium, American Museum of Natural History, October 13, 1952.

The History of the Chemical Elements

By Otto Struve, *Leuschner Observatory, University of California*

"THE CHEMICAL constitution of the universe is surprisingly uniform: . . . about 55 per cent of cosmic matter is hydrogen and about 44 per cent helium; the remaining 1 per cent accounts for all the heavier elements, in the same proportions as we find them on the earth," writes George Gamow, in his book, *The Creation of the Universe*. In other words, as J. L. Greenstein said* recently, "The stars are mainly hydrogen and helium, with an impurity of carbon, nitrogen, and oxygen, and only 'traces' of the other 90 elements."

Obviously, this cosmic distribution of the chemical elements does not apply to the earth, or to the other planets; nor does it apply to the meteorites, or to the particles that compose the zodiacal light and the counterglow. Both hydrogen and helium are almost nonexistent in the smaller bodies of the solar system, and even the oceans of the earth, consisting of only two atoms of hydrogen for one atom of oxygen, are by weight more oxygen than hydrogen. It is reasonable to suppose that this anomaly is entirely due to the escape of the lighter gases from the smaller bodies of the solar system. Presumably, these gases were ultimately driven out of the solar system by the pressure of the sun's radiation.

Yet, for the heavier elements, the composition of the earth closely resembles that of the sun, as may be seen in Table I, where the numbers listed are to powers of 10, by numbers of atoms. For example, in the sun a volume containing 10^{12} atoms of hydrogen has only $10^{1.19}$ atoms of lithium—a factor of nearly 100 billion.

The table gives two independent determinations of the abundances in meteorites, one by Harrison Brown, the other be H. C. Urey. They based their work upon slightly different assumptions regarding the nature of an average meteorite. The actual samples differ appreciably from one another — the iron meteorites containing more iron and nickel than the stony meteorites, which are rich in various kinds of silicates. However, for our purpose the two meteorite determinations are sufficiently similar to one another, and beginning with the element sodium (Na) they also resemble the abundances in the sun.

Table II lists the abundances of the elements in some of the hotter stars and in planetary nebulae. Here the observational data of A. Unsöld and L. Aller have been used extensively. This table furnishes the abundances of the lighter elements, such as carbon, nitrogen, neon, fluorine, sulphur, and so on, which are not normally observed in the sun. Yet we know that they must be present. Their spectral lines fail to appear because the temperature of the sun is too low to produce the required amount of excitation.

The two tables overlap in the case of oxygen: the solar abundance is $10^{8.88}$; the average abundance in the hot stars and nebulae is $10^{8.81}$. The agreement is perfect, and we are probably entitled to assume that both tables represent the basic "cosmic" abundances of the elements in the universe.

However, despite the large amount of work which has been done toward the determination of these abundances, the results are still uncertain by factors of the order of two or three. Even the important abundance ratio of hydrogen to helium is still quite uncertain. Table II gives $H/He = 10^{12}/10^{11.14} = 7$. Thus, for every atom of helium there are, supposedly, seven atoms of hydrogen. Since one helium atom weighs four times as much as one atom of hydrogen, the ratio by mass is 7:4, roughly that quoted from Gamow in our introductory sentence. Yet, recent work by Anne Underhill at Victoria leads to a ratio of about one helium atom to 20 or 25 hydrogen atoms, and her conclusion has been confirmed in an unpublished investigation by the Belgian astronomer, L. Neven, whose result is $H/He = 30$.

The uncertainty referred to has its origin in the different assumptions that have been made by different persons regarding the distribution of the temperature and pressure in a stellar atmosphere. Unsöld, whose work was the pioneering effort in this field, carried out about 10 years ago with the help of McDonald Observatory coude spectrograms, assumed an average value of the temperature and pressure, as if these were the same for all layers. On the other hand, Neven has tried to compute exactly how the temperature and pressure vary with height in the atmosphere. We do not know whether Unsöld and his collaborators, H. H. Voigt and others, will accept these new and appreciably smaller helium abundances. Until this whole question has been thoroughly discussed, we must suppose that even this important ratio is known only very roughly.

TABLE I — ELEMENT ABUNDANCES SUN AND METEORITES

Element	*Sun*	*Meteorites Brown*	*Meteorites Urey*	*Element*	*Sun*	*Meteorites Brown*	*Meteorites Urey*
H	12.00	——	——	Sr	2.88	3.11	3.11
Li	1.19	——	3.5	Y	3.2	2.50	2.49
O	8.88	——	——	Zr	2.4	3.68	3.65
Na	6.28	6.16	6.21	Cb	2.2	2.45	2.35
Mg	7.54	7.45	7.44	Mo	1.8	2.78	2.27
Al	6.23	5.45	5.41	Ru	1.3	2.47	1.82
Si	7.12	7.50	7.50	Rh	0.1	2.04	1.35
S	6.9:	7.04	6.49	Ag	0.6	1.93	1.78
K	5.15	5.34	5.04	Ba	2.52	2.09	2.02
Ca	6.42	6.33	6.25	La	1.4	1.82	1.82
Sc	3.3	2.76	2.73	Ce	2.0	1.86	1.86
Ti	4.96	4.92	4.76	Nd	1.6	2.02	2.02
V	4.05	3.90	3.68	Sm	1.1	1.58	1.54
Cr	5.20	5.48	5.41	Eu	1.0	0.95	0.95
Mn	5.40	5.39	5.33	W	−0.2:	2.77	2.61
Fe	7.09	7.76	7.33	Pt	1.2	2.44	1.68
Co	5.0	5.50	4.96	Hg	3.0:	——	−0.72
Ni	5.9	6.63	6.09	Pb	1.7:	<1.8	<1.8
Cu	4.5	4.16	4.12				
Zn	4.53	3.70	3.76				
Ge	2.6	3.90	3.54				

The number given is $\log_{10}$ of the number of atoms, with hydrogen normalized to +12. The meteorite abundances have been filled by adding 3.5.

It is particularly instructive to plot the relative abundances of the elements as the ordinates, with their atomic weights as the abscissae. This has been done in Fig. 1. The abundances are not quite the same as those listed in Tables I and II. Moreover, the abundance of hydrogen, instead of 10^{12}, is here given as about $10^{8.5}$. Therefore, if we wish to compare the diagram with the data of the tables, we must add to all the ordinates the number 3.5. For example, for helium we read from the diagram an ordinate of about 7.5. Adding 3.5 gives 11.0, which is close enough to the value of Table II, $10^{11.14}$.

The circles in Fig. 1 represent atoms of odd atomic number, hydrogen, lithium, and so on; the crosses stand for atoms of even atomic number, helium, beryllium, and so on. In a general way, the crosses correspond to larger abundances than the circles — a conclusion that is well known to chemists and physicists as Harkins' rule. Undoubtedly, it reflects the operation of an important nuclear process that was present when the elements were formed.

The diagram contains other valuable

TABLE II — ELEMENT ABUNDANCES HIGH-TEMPERATURE OBJECTS

Element	*Stars*	*Planetary Nebulae*
H	12.00	12.00
He	11.14	11.40
C	7.96	7.9
N	8.22	8.22
O	8.73	8.89
F	6.4:	5.5:
Ne	8.77	8.86
S	7.25	7.90
Cl	7.0	7.00
A	7.7:	6.90

* In a lecture on astrophysics at Michelson Laboratory, China Lake, Calif., on December 8, 1952. The data in Tables I and II were also presented at the lecture.

information. We notice that the distribution of the elements is not a random one. The largest abundance is that of hydrogen. This is followed by helium. These are joined smoothly by the abundances of carbon, nitrogen, oxygen, and the rest of the heavier elements. Thus, with the exception of a few very low values, which are for lithium, beryllium, and boron, the crosses and circles arrange themselves in a wide band which at first shows a rapid drop, as we pass from hydrogen to the heavier elements. After reaching atomic weights of the order of 100, the band levels off — indicating approximately identical abundances for the heavier elements.

Gamow's diagram contains far more data than are given in the tables. This is due to the fact that he has used all terrestrial abundances from the work of V. M. Goldschmidt, as supplemented by Brown's more recent measurements. Gamow has also included the abundances of the various isotopes, such as heavy hydrogen or deuterium, most of which are not observed in astronomical sources.

The low abundances of lithium and beryllium (the latter is not included in the tables, but Aller gives $10^{1.5}$ on the scale of our tables) are the most striking evidence we have of the operation of nuclear processes in the universe.

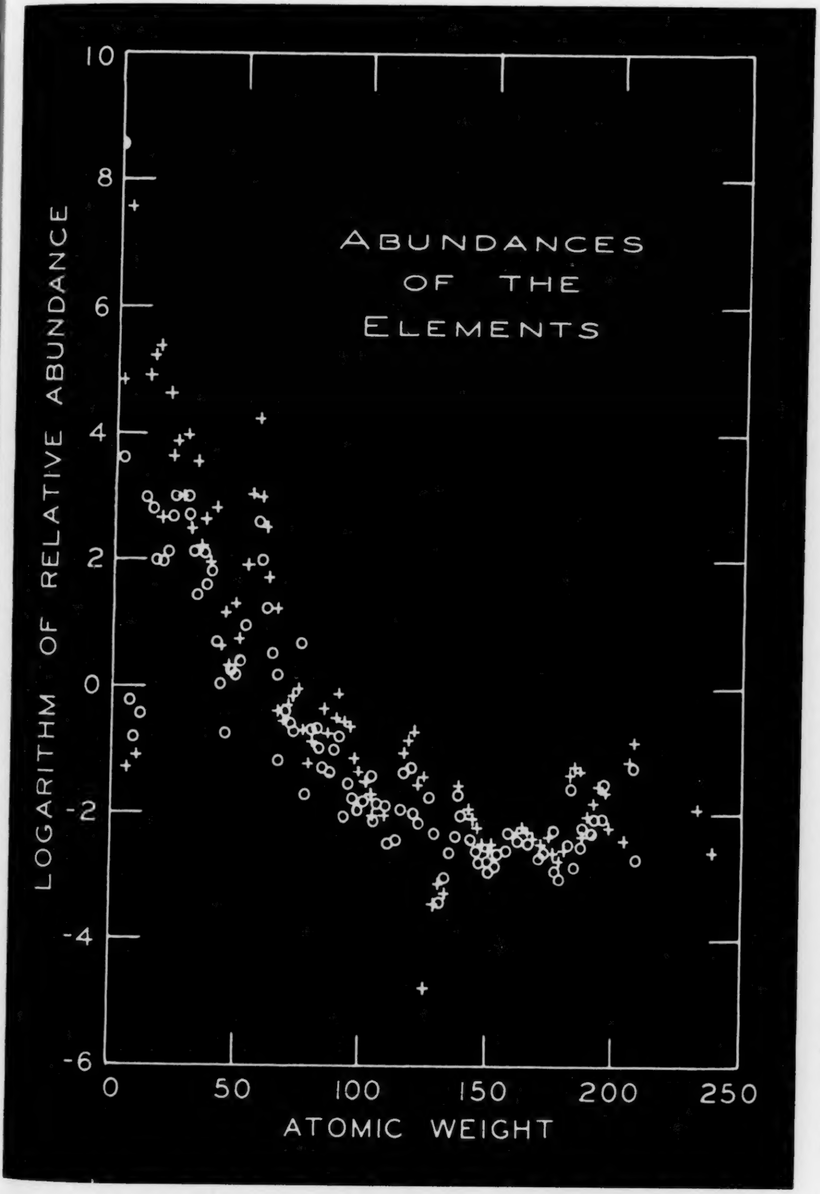


Fig. 1. In this chart, hydrogen is represented by the filled half-circle in the upper left; helium by a cross below it. The illustrations with this article are adapted from the book, "Creation of the Universe," copyright 1952 by George Gamow, with permission of the Viking Press, Inc., New York.

From laboratory experiments we know that both elements are capable of capturing protons, the mutual repulsion between the nucleus of the element and the proton being overcome at relatively low temperatures — about a million degrees would suffice. A lithium atom of mass 7 becomes a new element of mass 8, which rapidly disintegrates into two normal helium atoms of mass 4.

Temperatures of the order of a million degrees are not so rare in the stars, and we need not descend into the far depths of the sun to find conditions where lithium and beryllium must be quickly converted into helium. But is the present low abundance of lithium and beryllium mainly the result of nuclear processes that are going on at the present time, or were these elements turned into helium ashes in a prestellar medium which may have possessed a uniformly high temperature of many millions of degrees?

A partial answer to this question comes from Table I. Greenstein and R. S. Richardson found a solar abundance of lithium equal to $10^{1.19}$. Urey obtained a value of $10^{3.5}$ in the meteorites. Thus, lithium is more than 100 times as abundant in the meteorites as it is in the atmosphere of the sun. In the meteorites, nuclear processes are absent, because temperatures are not sufficiently high. In the sun, as we have seen, an atom of lithium need only descend, by convection, to a depth of a thousand miles or so below the surface, and it will be converted into helium. The conclusion is inescapable that the original medium out of which sun, planets, comets, and meteors were formed contained at least $10^{3.5}$ atoms of lithium for every 10^{12} atoms of hydrogen. The abundance in the sun was still further reduced by a factor of 100, after the sun reached its present internal temperature. In the meteors, on the other hand, the abundance remained the same, $10^{3.5}$.

Of course, even this abundance falls way below the band in Gamow's diagram. We must therefore suppose that the original gaseous and dusty medium out of which stars are formed was to begin with deficient in lithium and beryllium. This is supported by Lyman Spitzer's announcement that the interstellar gas contains very little lithium and beryllium. How little, we do not know, because the spectral lines of these elements are too weak to be seen at all. Spitzer is currently engaged in an effort to overcome this difficulty by means of observations at the Mount Wilson 100-inch telescope.

But even if we should find that the abundance of lithium in the interstellar gas is similar to that in meteorites, or even in the sun, we shall still not know whether the burning-out process occurred in a prestellar state of our galaxy,

many billions of years ago, or whether what we now observe as interstellar gas clouds may have been expelled from the surfaces of novae and other expanding stars. In the second case, the burning-out could have taken place in these stars, and within the three-billion-year interval during which our galaxy has remained essentially what it is now.

A few years ago, A. McKellar at Victoria discovered several stars with exceptionally strong absorption lines of lithium. Although the surfaces of these stars are cooler than the sun's surface, there can be no doubt that their internal temperatures are more than sufficient to convert, rapidly, all lithium into helium. The actual lithium abundances in these stars have not been determined. But it is fairly certain that they exceed the abundance in the sun by a factor of many thousands. How, then, can we explain the presence of so much lithium in McKellar's stars and so little of it in the sun? One suggestion is that the surface material of McKellar's stars never travels much below the surface: there are no convection currents. Even on the sun, the evidence is strongly in favor of a relatively *mild* degree of mixing — otherwise, *all* the lithium would have disappeared a long time ago.

Another possibility is that lithium is being newly produced in the stars. One process for such production, considered by Fermi and Turkevich, is that a normal helium atom combines with an atom of tritium (the hydrogen isotope of mass 3). The result is the creation of a lithium atom of mass 7, and the production of a quantum of gamma radiation. However, to be efficient this nuclear reaction requires an enormous temperature, much higher than the 20 million degrees in the interiors of many stars. If this method of building up lithium in stars occurs at all, it must be confined to regions where the conditions differ markedly from those that prevail on the average. But we know that the stars are tremendously complex structures. Even the sun, a relatively quiescent dwarf, has hot spots with flares, has regions of high magnetic activity, has tremendous up-and-down surges of material in the form of prominences, and is surrounded by a tenuous coronal envelope whose temperature is a million degrees. Is it not possible that there are localized regions, either on the surface or a short distance below it, where atoms like lithium are being formed? If so, then these newly created atoms are being constantly destroyed in the deeper layers by the conversion of lithium into helium.

An analogous question arises when we consider P. W. Merrill's recent discovery of strong absorption lines of technetium in several late-type variable stars. Technetium, which follows the normal and stable element molybdenum in the periodic table, is neither normal nor stable. It does not exist on the earth under natural conditions, and it was first produced artificially in the year 1937 by E. Segrè and several other physicists from molybdenum samples exposed to intense bombardment with deuterons in the Berkeley cyclotron. Its absence on the earth is due to the fact that its mean life is only 200,000 years. In two million years, less than 1/10 of the original amount of technetium would be left — the disintegration being of the radioactive type, which is independent of the temperature and pressure.

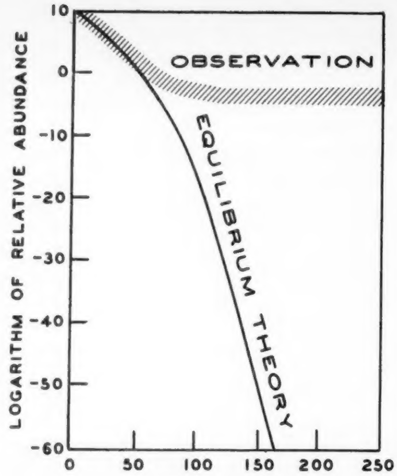


Fig. 2. The abundances of the elements as they would be established according to the theory of "frozen equilibrium" fits the present observed abundances for the lighter elements, but fails completely to match the relative quantities of the heavy elements.

The large abundance of technetium in Merrill's *S*-type stars is one of the greatest mysteries of our physical universe. The physicists believe that there is a remote possibility that a stable isotope of technetium may exist, but in that case the absence of this element on the earth would remain wholly unexplained. At the present time it appears more likely that some local phenomena on the surfaces of *S*-type stars continuously create new technetium atoms, which are then subjected to radioactive decay and end up in the form of other, stable elements.

It seems to me that the importance of local phenomena in creating various kinds of heavy atoms in stars has not been sufficiently appreciated in the past. It is true that we have at present little, if any, information regarding the nature of these hypothetical local processes that we invoke to account for the continuous creation of lithium, technetium, and perhaps other heavy atoms. But we should remember that we are here concerned only with the production of "traces" of elements — occasional freak atoms that may happen once in a hundred billion tries. Let me use an analogy to explain what I mean.

The earth, with its low temperature, is certainly not now a "cauldron" in which atoms are being brewed on a large scale. Yet if an astronomer on a hypothetical planet of Alpha Centauri should be observing the spectrum of the earth four years after the detonation of the first real hydrogen bomb, he might find to his surprise that "traces" of helium had appeared where no helium was previously in existence. Since he would know that on a grand scale the creation of helium out of hydrogen does not occur on the earth (as distinct from the creation of helium through radioactive decay in the rocks), he would conclude that a localized phenomenon on the earth, though inappreciable in the grand scale of the universe, had resulted in the formation of traces of elements that should not normally be present at all. If, then, such localized phenomena can occur on the earth, is it not reasonable that much more powerful local "ovens" exist on the stars where the conditions are sufficiently different from average to permit the formation of heavy elements?

We should probably distinguish between nuclear processes in stars on a grand scale, such as the conversion of hydrogen into helium, and freak nuclear processes which only very rarely produce a heavy atom. The former must occur in large volumes within the stars, and must in practice be realizable under the average conditions of internal stellar temperatures and pressures. The latter need not occur at all under such average conditions. What they require is a local hot spot or other anomalous region on a star, such as a *natural* cyclotron or betatron.

The grand-scale process of conversion of hydrogen into helium is now familiar to most readers of this magazine. It is required to explain the energies of stellar radiations, and it finds a satisfactory confirmation in the theory of stellar evolution which I described in the January issue. But do we have any direct observational evidence from the spectra of the stars that the old stars are deficient in hydrogen and rich in helium? The strange thing is that we do not.

It is true that D. M. Popper and W. Bidelman in this country, and A. D. Thackeray and A. J. Wesselink in South Africa, have discovered some stars whose spectra are strangely lacking in hydrogen lines. But these are few in number, and they are not the ones we would have expected, on other grounds, to show low hydrogen-helium ratios. For example, we believe that the hotter stars in the Pleiades are older, and therefore more advanced in the nuclear time-scale than the hottest stars in the cluster h and Chi Persei (see my articles in the January *Sky and Telescope* and the March *Scientific American*). Yet, the stars of the Pleiades have fairly strong lines of hydrogen.

We could evade this difficulty by suggesting that there is no mixing of atmospheres of the Pleiades with their interiors — in which case the compositions of the atmospheres would not reflect the changes in the stellar interiors. But the Pleiades are rapidly rotating stars, and on other grounds we believe that rapid rotation aids in the process of mixing. Conversely, we might think that the Popper-Bidelman stars are old and are subject to efficient mixing by convection. But there is no reason to believe that in these particular stars mixing is more efficient than in the hotter members of the Pleiades. We are confronted with a mass of contradictory data and conclusions. Perhaps here, too, we shall have to consider departures from normal conditions in localized regions of the hydrogen-deficient stars.

One of the strangest results of stellar spectroscopic investigation is the low abundance of the metals relative to hydrogen in the stars of Baade's Population II. First announced by Schwarzschild, Spitzer, and Wildt, this result has been amply confirmed by other workers. Yet the Population II stars are the "oldest" objects in our galaxy. Their high relative abundance of hydrogen is probably due to two causes. First, these stars are evolving slowly; they are not sufficiently luminous to exhaust a large fraction of their original supply of hydrogen in three billion years. Second, they may have had relatively more hydrogen to begin with than do the young stars in the solar neighborhood. The latter have, in part, grown out of interstellar dust clouds, and these are almost certainly deficient in hydrogen. Dust particles, like molecules, can contain only comparable numbers of hydrogen and heavier atoms. Ice crystals, for example, when impinging upon a newly formed star, would contribute only two atoms of hydrogen for every atom of oxygen.

What can we say, in general, about the origin of the elements? A few years ago, when it became apparent that under normal stellar conditions no heavy atoms can be produced, and only the process $4H \rightarrow He$ is of real importance, the tendency was to suppose that the distribution of the heavy elements could only be accounted for by assuming a prestellar state of matter at a very high temperature and pressure, in which the atoms were formed.

This led to the "equilibrium" theory corresponding to a given, very high temperature, and it resulted in a distribution of the elements that became "frozen" when the internal stellar temperature dropped to 20 million degrees. But as Gamow and others have remarked, the equilibrium theory leads to a distribution that can be adjusted to represent the elements of atomic weights less than about 60, but departs violently

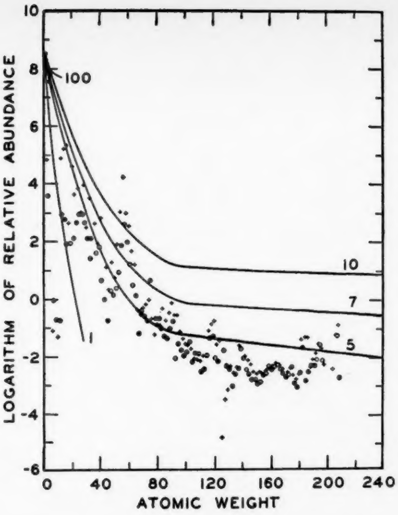


Fig. 3. Abundance curves based on the theory of atom building by successive neutron capture, calculated for different density constants by Alpher and Herman on the electronic computer of the National Bureau of Standards.

from the observations for the heavier elements (see Fig. 2).

To overcome this difficulty, one could think not of a single brewing cauldron, but of successive stages corresponding to different temperatures. The earliest stage, presumably at the highest temperature, produced a distribution rich in very heavy elements. A later stage, at a somewhat lower temperature, did not disturb the first "frozen" set of abundances, but modified very greatly the abundances of the lighter elements. On this view we are now in the last stage of element brewing. Our present universe has all the abundances of the heavier elements frozen from one of the prestellar stages. But we are still converting hydrogen into helium.

A different and in some respects very attractive modification of this picture has been given by Gamow and his associates. This theory has been presented in popular form in *The Creation of the Universe.* It starts with a hot nuclear gas consisting, to begin with, mostly of neutrons, protons, and electrons. The gas had a temperature of many billions of degrees, and expanded so rapidly as to prevent the setting up of an equilibrium between different kinds of particles and the prevailing temperature and pressure. The theory is too complicated to be discussed here in detail, and I refer the reader to Gamow's book. It presents a breathtaking flight of the imagination, but it contains so many departures from conventional ideas that it is apt to shock the more conservative reader. Yet, it must be admitted that it leads to a rather beautiful explanation of the abundance curve. In Fig. 3, the four curves correspond to four different assumptions concerning the initial density of the primordial medium, which Gamow calls *ylem,* "reviving an obsolete noun which according to Webster's *Dictionary* means the first substance from which the elements were supposed to be formed."

Opposed to the theories of a prestellar ylem are those of J. B. Van Albada and especially F. Hoyle, who believe that the abundances of the elements can be explained if we assume that especially powerful processes occur in the red giants (Van Albada) and in the exploding supernovae (Hoyle). In principle, their theories are similar to the ideas presented earlier in this article, except that I would be inclined to look for small atomic brewing ovens in a large variety of stars — perhaps even in the sun.

AMERICAN ASTRONOMERS REPORT

(Continued from page 150)

tional two-color measurements, again using the 100-inch telescope, and he has extended his limit to galaxies in clusters that have velocities of recession up to 60,000 kilometers per second or one fifth of the speed of light. His new observations confirm the previous findings—the reddening is still too great by a factor of two.

On the other hand, four late-type spiral galaxies with velocities in the range of 22,000 to 27,100 kilometers per second were found to be very blue, with observed international color indices from +0.32 to +0.50; the excess found in the ellipticals seems definitely to be absent. This difference in color of the two general types seems to give support to the idea that aging has a different effect on the ellipticals than on the spirals.

A multicolor photoelectric study of the brightest elliptical nebula in the Corona Borealis cluster, however, yielded a differential energy curve relative to M32 over the range from 3400 to 8300 angstroms. (M32 is the companion of the great Andromeda spiral that has been used by Dr. Whitford as a standard elliptical system, and it has been checked in this respect with other ellipticals in the relatively nearby Virgo cluster.) The result is definitely not that to be expected from the death of red giants in the ellipticals, which was the age-effect explanation first suggested, by Schwarzschild. In fact, the observed differences are not to be explained by the addition or subtraction of any one type of star.

The observed two-color excess for all the ellipticals, however, could arise from additional radiation in the distant systems by the addition of some yellow supergiants in each case. Preliminary results on the brightest system in the Bootes cluster, where the effect is larger and should be less affected by random intrinsic color differences, are consistent with this view.

NEWS NOTES

By Dorrit Hoffleit

EXPENSIVE BEQUEST

At first sight the bequest to an astronomical society of twin 15-inch photographic and visual refractors would seem to be a godsend. Regrettably, this is not the case in the event the cost of moving and mounting the instruments is greater than the organization can bear.

Under the will of the late Dr. Wilfred Hall, the telescopes of his private observatory in Newcastle were left to the British Astronomical Association for scientific research, or, failing its acceptance, to the Royal Astronomical Society. The BAA has determined that too few of its members could use the telescopes at any one location to justify even half the expense involved. If the RAS likewise finds itself unable to accept the bequest, the instruments must be sold, the proceeds reverting to the original estate and not benefiting astronomy.

NEW SUBSTANCE FOR LENSES

A new patent issued to Leon Merker, of New York, and Langtry E. Lynd, South Plainfield, N. J., and assigned to the National Lead Company, concerns a new optical substance that has a high refractive index and low reciprocal relative dispersion. It is a compound of strontium and titanium, monocrystalline strontium titanate, and is prepared at 2,100° centigrade with the aid of an oxygen-hydrogen torch, according to Science Service.

Optical material with these characteristics is particularly useful for reducing aberrations in lens systems of wide field and small focal ratios.

ASTEROID NAMES

What are the meanings of the names of the asteroids? In the *Strolling Astronomer* (October 1, 1952), Anthony Paluzié-Borrell, of Barcelona, describes his unusual hobby of attempting to ascertain these meanings for the more than 1,560 minor planets that have already been catalogued. By searching ancient and modern literature and by an active correspondence, he has found the origins and meanings of all but 150 names. These remain without known significance, chiefly because the discoverers of those asteroids have long been dead.

Among the examples of interesting asteroid names given by Mr. Paluzié-Borrell are two in which he has had a part. In his correspondence he sometimes used the international language, Esperanto, and two of the asteroids discovered by his Finnish friend, Dr. Y. Vaisala, were consequently named Esperanto and Zamenhof (its inventor).

No. 1372, Haremari, is compounded of the word *harem* and the initials of the Astronomische Rechen Institut, in honor of its women computers of minor planet orbits. No. 694, Ekard, was named by the Nicholsons while they were students at Drake University. They were the first to compute its orbit, and Ekard is Drake spelled backwards.

ZODIACAL LIGHT OBSERVED BY SEA CAPTAIN

The zodiacal light, best seen in the tropics, has long been one of the controversial topics in solar-system astronomy. Recently a retired Dutch sea captain, Jan Drent, enrolled in a geophysics seminar at the University of California at Los Angeles. There he presented observations made during years of navigation to and from the Dutch East Indies. His data, reduced with the aid of geophysicists Robert E. Holzer and Louis Schlichter, indicate that the major axis of the zodiacal light lies in the general plane of the orbits of the major planets, instead of in that of the earth's orbit, where many astronomers had thought it to be.

ADOLPH LOMB MEDAL

The 1952 recipient of the Adolph Lomb medal of the Optical Society of America was Dr. Aden B. Meinel, Yerkes Observatory astronomer. The award is made biennially to a scientist under 30 years of age for achievement and promise in any field of optics. Dr. Meinel, who spent two years with the Jet Propulsion Laboratory at the California Institute of Technology and two with the Navy during the war, obtained his Ph.D. degree at Lick Observatory in 1949.

His thesis, a spectrographic study of the night sky and the aurora in the near infrared, is the basis of the work which is being recognized by the award. He designed a Schmidt-type lens and transmission grating with a 9-inch aperture, focal ratio f/0.8, and a flat field for wave lengths from 3000 to 9000 angstroms. In the night sky spectrum, he discovered or identified emission bands of OH, oxygen and nitrogen molecules, and of neutral oxygen and nitrogen atoms. His measurements of the Doppler effect demonstrated the presence of high-velocity protons entering the upper atmosphere at times of auroral displays.

IN THE CURRENT JOURNALS

COLLISIONS WITH HEAVENLY BODIES, by E. J. Opik, **Irish Astronomical Journal,** December, 1952. "As far as its neighbours in the solar system are concerned, the earth enjoys a safe and undisturbed position, no lethal changes from collisions with other bodies being imminent."

PLANETS FROM PALOMAR, by Alice Beach, **Scientific American**, February, 1953. "To get better pictures than those shown here, therefore, we must wait until favorable positions of the planets coincide with nearly perfect seeing conditions."

THE CANALS OF MARS, by Thomas R. Cave, Jr., **Griffith Observer**, February, 1953. ". . . the greatest observational evidence points to the reality of the linear detail upon the surface of Mars. Its true nature yet remains to be discovered."

MICHIGAN SYMPOSIUM ON ASTROPHYSICS

From June 29th to July 24th, the University of Michigan will conduct a symposium on astrophysics that will have great interest for all students of astronomy. The other part of the regular summer symposium will be on X-ray diffraction. The schedule is:

June 29-July 24: Dr. Walter Baade, Mount Wilson and Palomar Observatories, "Galaxies, Their Composition and Structure" (12 lectures).

June 29-July 10: Dr. George Gamow, George Washington University, "Evolution of Stars and Galaxies" (6 lectures).

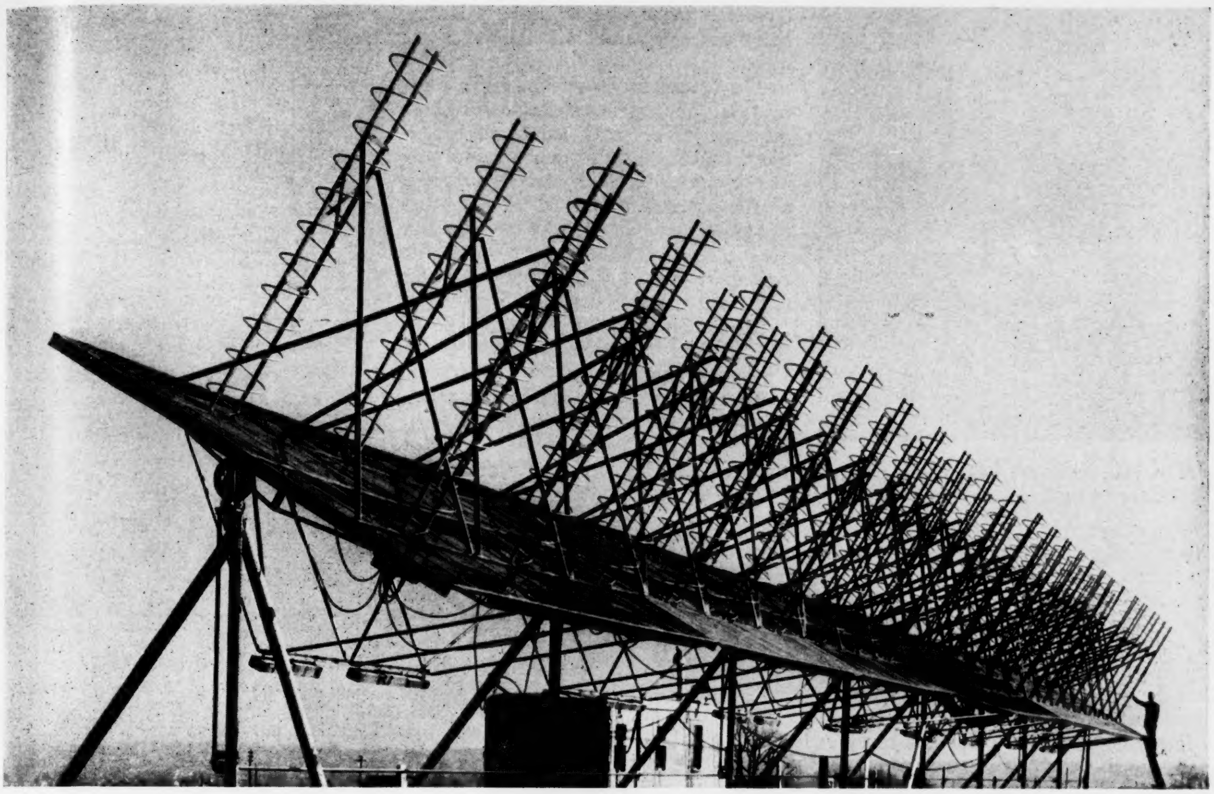
July 13-24: Dr. G. K. Batchelor, University of Cambridge, "Turbulence in Stars and Nebulae" (6 lectures).

July 13-24: Dr. E. E. Salpeter, Cornell University, "Nuclear Transformations and Stellar Energy Generation" (6 lectures).

Further information and details of housing arrangements may be obtained from Prof. Leo Goldberg, University of Michigan Observatory, Ann Arbor, Mich. A grant from the National Science Foundation permits the appointment of a small number of symposium associates, whose travel and living expenses are paid. Advanced graduate students and doctoral degree holders less than 30 years old on January 1, 1953, should request application forms by April 10th from the Office of the Summer Session, University of Michigan, Ann Arbor, Mich.

ASTRONOMY BY TV

"College courses in your living room," conducted by Butler University over WFBM-TV, Indianapolis, Ind., include a course in general astronomy, which began on January 29th and will continue through May 25th. Dr. Harry E. Crull, director of the University College and head of Butler's mathematics department, is the television instructor. The course was offered for three hours of college credit, at a tuition fee of $45. Final examinations are given at the university, with special arrangements made for shut-ins. For a two-dollar fee, a syllabus is furnished non-credit course registrants.



The Ohio State radio telescope consists of 48 helical beam antennas. Ohio State University photograph.

The Ohio State Radio Telescope

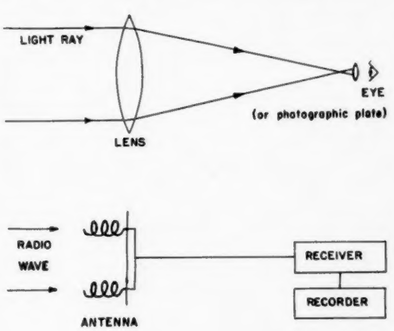
By John D. Kraus, *Ohio State University*

RADIO WAVES are electromagnetic in nature, the same as is light, but they are a million times longer, so that although many similarities exist between radio and optical astronomy there are also very significant differences. For example, at radio wave lengths the strong sources are not the bright stars but other objects for the most part of undetermined nature. The sun is also a strong radio source but it is not, relatively speaking, the prominent object that it is visually, other objects or regions being of comparable intensity.

Although the techniques used in optical and radio astronomy are analogous, they offer a sharp contrast. In place of a lens or mirror for collecting and focusing light an antenna system collects radio waves, and in place of the eye or photographic plate a radio receiver and pen are used for detecting and recording the radio signals. Thus, by analogy, the antenna or even the entire antenna-receiver system may be referred to as a radio telescope, although it may bear little resemblance to its optical counterpart.

Radio waves penetrate interstellar gas and dust more readily than light and hence should provide us with more detailed information about the structure of our own galaxy, large portions of which are hidden from visual observation by clouds of interstellar matter. Furthermore, the radio waves are unhindered by atmospheric clouds, so that radio observations may be made in cloudy weather and clear, day and night.

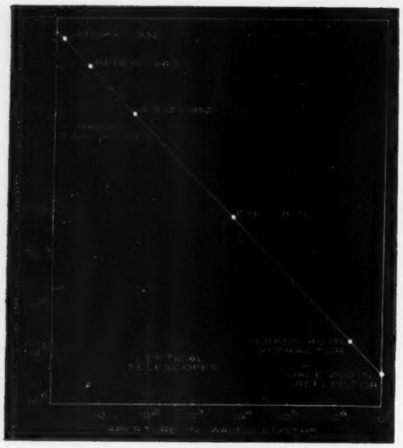
On the other hand, radio astronomy suffers from the fundamental disadvantage of limited resolution. The resolving power of an optical or radio telescope is directly proportional to the aperture expressed in wave lengths. To see what this means let us consider the human eye, with an aperture (pupil diameter) of about one-eighth inch, which is about 6,000 wave lengths of light. To equal the resolution of the unaided eye, a radio telescope antenna would also need to be 6,000 wave lengths across; at a wave length of one meter this amounts to nearly four miles. Or in an extreme case, to obtain the resolution of the 200-inch Hale telescope at this wave length would require a radio antenna with a diameter about equal to that of the earth.



This diagram shows analogous parts of optical and radio telescopes.

Radio astronomy dates from K. G. Jansky's discovery in 1932 of radio waves of extraterrestrial origin, while its emergence as a science stems largely from Grote Reber's subsequent galactic surveys. Since World War II it has developed rapidly. Nevertheless, the science of radio astronomy is very much an infant, being in the same relative state of development as optical astronomy in the days of Galileo.

On August 1, 1952, a new radio telescope was put into operation at Ohio



A comparison of resolving power versus aperture for optical and radio telescopes.

State University. The antenna, shown in the photographs, consists of 48 helical beam antennas mounted in an array 160 feet long. The helix axes point in the direction of maximum response of the antenna. The entire array pivots on a horizontal east-west axis over a range in declination from 40 degrees south to 90 degrees north. The antenna pattern is fan-shaped, with a beam width between half-power points (equivalent to resolving power) of less than one degree in right ascension and 15 degrees in declination, with 48 helices at a frequency of 300 megacycles per second. As with a transit-type telescope, the antenna pattern sweeps across the sky in right ascension as the earth rotates, the intensity of the received signal being recorded by a pen on a moving paper tape.

All helices must be wound in the same direction for the array to have maximum resolution. The helices in the Ohio State antenna are right handed and, hence, responsive to the right-circularly polarized component of the incident radiation. On occasion, some of these helices are replaced with left-handed types for measurements of the polarization characteristics of the received waves.

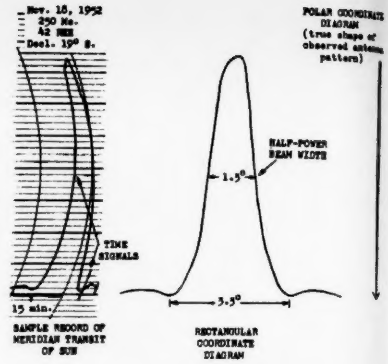
The helical beam antenna is used because of its wide-band frequency characteristics,* the array being usable over the frequency range from 200 to 300 megacycles per second, and also because of the absence of mutual coupling between helices. There appears to be no practical limit of the size to which this type of array can be built, its cost being almost directly proportional to its length (rather than to the square or cube of the diameter, as is often considered true for optical telescopes).

A sample record of the meridian transit of the sun using 42 helices at 250 megacycles per second is presented (at top left) in the accompanying illustration. An Esterline-Angus recorder is used with the pen moving along the arc of a circle, which accounts for the bent appearance of the trace. When plotted in rectangular co-ordinates the record appears as in the center graph. When redrawn in polar co-ordinates the pattern appears as at the right. This polar pattern gives one a true picture of the sharpness of the observed antenna pattern in right ascension. Since the disk of the radio sun subtends an angle of at least half a degree, the pattern is somewhat broader than the actual antenna pattern obtained with a point source.

Each section or group of six helical antennas connects through a broad-band transformer to a single coaxial cable. Eight such cables connect to the receiving system in a trailer adjacent to the antenna. Either a single-lobe pattern (as shown) or a split-lobe type can be produced by proper phasing of the antenna sections.

The receiver employs several stages of radio frequency preamplification, a su-

* Kraus, J. D., *Antennas*, McGraw-Hill Book Co., Inc., New York, 1950, pp. 173-216.



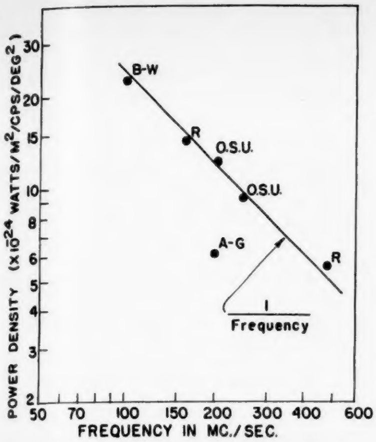
Midday records of solar radio radiation (above), and a saw-tooth record.

perheterodyne unit, AC and DC amplifiers, and a recorder. The recorder deflection is proportional to the power collected by the antenna. It is convenient to compare this power at intervals with the noise power of a matched resistor at room temperature. In the sample record with a saw-tooth curve, this is done at intervals of about four minutes, with the receiver connected to the antenna for three minutes and then to the resistor for one minute. When the antenna power is less than the resistor power, the antenna is receiving power from a portion of space that is colder than room temperature. On the other hand, when the antenna is pointed at a radiating object (the sun at transit in the record), the antenna power can exceed the resistor power. The entire system may be regarded as a bolometer or temperature-measuring device which indicates the difference between room temperature and the temperature of that portion of space to which the antenna is responsive. Instead of making the comparison at the slow rate of once in four minutes, the comparison rate is normally about 25 times per second. This is too rapid for the pen to follow, and a Dicke-differential system is employed to record only the *difference* between the antenna and resistor powers.* All records shown, except for the saw-tooth sample, are of this kind.

The telescope began operation on August 1st with 12 helical antennas. In the following weeks additional sec-

* Dicke, R. H., "Measurement of Thermal Radiation at Microwave Frequencies," *Review of Scientific Instruments*, July, 1946, 268-275.

A view from beneath of the antenna of the radio telescope when it was partly completed. Note the declination circle, in the lower left midway along the length of the array. Ohio State University photograph.



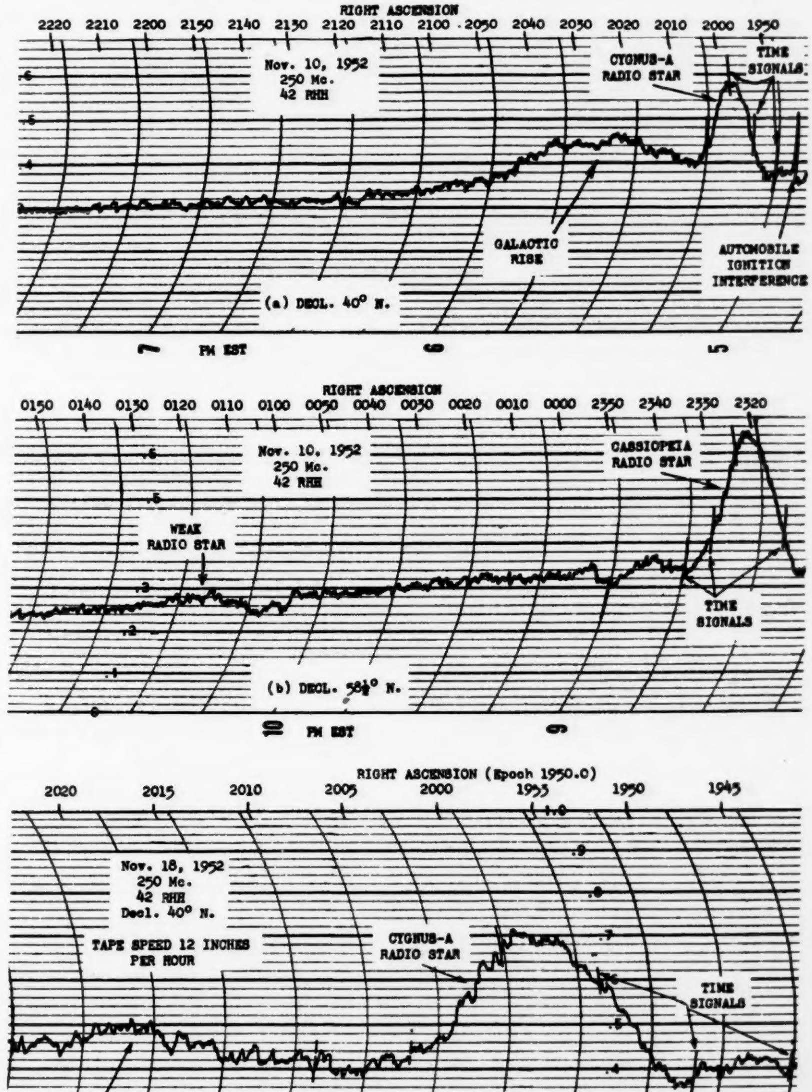
A power-frequency (or spectral) curve for the center of the galaxy. In addition to the Ohio State (O.S.U.) observations, values are given as obtained by Bolton and Westfall (B-W), Allen and Gum (A-G), and Reber (R).

tions were installed and connected, until late in October a total of 48 helices had been installed, with 42 right-handed helices connected as a high-resolution array, the remaining six being left-handed at that time. A survey of the entire sky observable from Columbus, Ohio, was made with the 12 to 24 helices that were first connected, and the results were reduced to a contour map showing the flat disk-like form of our galaxy with a general appearance much similar to that revealed by Reber's early surveys. These measurements were made in terms of the absolute power received, expressed in watts per square meter per cycle per second band-width per square degree of solid angle multiplied by 10^{-24}.

The absolute power received from the direction of the center of our galaxy (R.A. $17^h\ 51^m$, Dec. $-26°$) is indicated by the points designated "O.S.U." in the accompanying figure. Measurements of this value were made at 205 and 250 megacycles per second. By way of comparison, the values obtained by other observers at other frequencies are also presented, and it is apparent that the power varies (in the 200-megacycle region) very nearly as the reciprocal of the frequency.

More recently, effort has been centered on precision determinations of the location of the Cygnus and Cassiopeia radio "stars." Records are shown for these, taken at a paper-tape speed of three inches per hour. Of interest is the rise in signal following the Cygnus radio star as the antenna pattern sweeps through the center of the galactic plane. For accurate position determinations another record is simultaneously made at 12 inches per hour tape speed. A sample of such a record taken on the Cygnus-A star is also shown. Time signals from WWV are impressed at five-minute intervals. These time signals can be seen in the figures. The effect of interference from an automobile ignition system can also be seen in one of the figures, produced by an automobile leaving the observatory at 4:55 p.m. This type of interference is usually not troublesome, the observatory being situated on the university farms remote from highways.

The radio telescope project has been supported by grants from the Caroline Drew Lovejoy memorial fund, the O.S.U. development fund, and the O.S.U. Research Foundation. Much of the construction has been done by the department of electrical engineering shops, John D. Cowan, supervisor. Professors C. H. Wall and C. F. Purtz, of the department of civil engineering, have provided an accurate east-west base line used for measurements on the orientation of the telescope axis. A number of graduate and undergraduate students, the former on O.S.U. Research Foundation assistantships, have aided the project greatly. Their efforts are now turning from construction to observation; Sol Matt, of Cleveland, is studying the Cassiopeia radio star, while Edward Ksiazek, of the University of Vermont, is beginning observations on the Taurus radio star which is presumably the Crab nebula. The interest, cooperation, and counsel of the staffs of the McMillin and Perkins observatories are gratefully acknowledged.



The top and center records were taken November 10, 1952, with 42 helices at a tape speed of three inches per hour; the bottom record was taken November 18, 1952, at 12 inches per hour.

Amateur Astronomers

PLANETARIUM FOR PROVIDENCE

A special drive to raise a fund for a planetarium for the Roger Williams Park Museum in Providence, R. I., has been successfully concluded. Skies Unlimited, the community-wide fund-raising project, "sold" celestial real estate, stars, constellations, and planets. In a total of over $11,000, the largest single contribution was $250, and the smallest was one penny. The public school children of the city donated $1,100. Towns in the vicinity also supported the fund drive.

The Spitz projection instrument is already on hand, and a 24-foot plastic dome will be installed this spring, according to Miss Maribelle Cormack, director of the museum. The seating capacity will be about 80. School programs are planned, as well as special classes for museum astronomy and navigation students. Public showings on weekends and holidays will be free. The planetarium will be open each Friday night throughout the year for the Naval and Marine Training Center at Edgewood, R. I. In addition to the museum staff, volunteer lecturers will be furnished by the Skyscrapers, Rhode Island's amateur astronomical society.

The chairman of the fund drive was Mrs. Charles Potter, and the treasurer, Frank L. Martin.

THIS MONTH'S MEETINGS

Buffalo, N. Y.: Buffalo Astronomical Association, 8 p.m., Buffalo Museum of Science. Apr. 1, George F. Goodyear, Buffalo Museum of Science, "Space Travel."

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory. Apr. 17, Dr. G. Keller, Perkins Observatory, "Atomic Energy from the Stars."

Dallas, Tex.: Texas Astronomical Society, 8 p.m., Mercantile National Bank auditorium. Apr. 27, staff geologist, Magnolia Petroleum Co., "Structure of the Earth."

Geneva, Ill.: Fox Valley Astronomical Society, 8 p.m., City Hall. Apr. 14, Dr. Gilbert Raash, state geologist, title to be announced. Apr. 25, 6:30 p.m., annual banquet.

Indianapolis, Ind.: Indiana Astronomical Society, 2:15 p.m., Cropsey Hall. Dr. Frank K. Edmondson, Indiana University, "The Rome Meeting of the International Astronomical Union."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. Apr. 1, Rev. Francis J. Heyden, S. J., Georgetown Observatory, "Eclipse in Africa."

Port Arthur, Tex.: Port Arthur Astronomy Club, 7:30 p.m., club room, Coca Cola Co., 1616 Woodworth Blvd. Apr. 9, Dr. H. E. Eveland, Lamar State College of Technology, "Origin of the Earth." Apr. 23, G. F. Landegren, Lamar State College of Technology, "Planetary Atmospheres." Observation party.

Rutherford, N. J.: Astronomical Society of Rutherford, 8 p.m., YMCA. Apr. 2, John H. Loebbick, "Atmospheres of the Planets."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Building auditorium. Apr. 4, Fred Haddock, Naval Research Laboratory, "The Nature of Radio Astronomy."

ASTRONOMICAL LEAGUE MEMBERSHIP

The membership in the Astronomical League now consists of 68 societies, of which 64 are regular member groups and four are junior member organizations. Three of the adult societies have affiliate junior sections. In addition, there are 21 members-at-large. The membership by regions on February 1st was:

Region	Societies	Approx. Members
Middle East	17	1,050
Mid-States	5	175
North Central	6	350
Northeast	18	1,350
Northwest	4	125
Southeast	10	300
Southwest	5	234
Unaffiliated	3	100
Totals	68	3,684

Planetarium Notes

BALTIMORE: *Davis Planetarium.* Maryland Academy of Sciences, Enoch Pratt Library Building, 400 Cathedral St., Baltimore 1, Md., Mulberry 2370.

SCHEDULE: 4 p.m. Monday, Wednesday, and Friday; Thursday evening, 7:45, 8:30, 9:30 p.m. Admission free. Spitz projector. Director, Paul S. Watson.

BOSTON: *Little Planetarium.* Boston Museum of Science, Science Park, Boston 14, Mass. Richmond 2-1410.

SCHEDULE: Tuesday through Friday, 3 and 4 p.m.; Saturday, 11 a.m., 2, 3, and 4 p.m.; Sunday, 2, 3, and 4 p.m. Spitz projector. Acting director, John Patterson.

BUFFALO: *Buffalo Museum of Science Planetarium.* Humboldt Parkway, Buffalo, N. Y., GR-4100.

SCHEDULE: Sundays, 2:00 to 5:30 p.m. Admission free. Spitz projector. For special lectures address Elsworth Jaeger, director of education.

CHAPEL HILL: *Morehead Planetarium.* University of North Carolina, Chapel Hill, N.C.

SCHEDULE: Daily at 8:30 p.m.; Saturday and Sunday at 3:00 p.m. Zeiss projector. Manager, A. F. Jenzano.

CHARLESTON, W. VA.: *Hillis Townsend Planetarium.* Public Library Building, Charleston, W. Va.

SCHEDULE: Saturday, 11:15 a.m. Special showings on request. Admission free. Spitz projector. Director, Louise L. Morlang.

CHICAGO: *Adler Planetarium.* 900 E. Achsah Bond Drive, Chicago 5, Ill., Wabash 1428.

SCHEDULE: Mondays through Saturdays, 11 a.m. and 3 p.m.; Sundays, 2:00 and 3:30 p.m. Zeiss projector. Director, Wagner Schlesinger.

KANSAS CITY: *Kansas City Museum Planetarium.* 3218 Gladstone Blvd., Kansas City 1, Mo., Chestnut 2215.

SCHEDULE: Saturday, 3:00 p.m.; Sunday, 3:00 p.m. Spitz projector. Director, Charles G. Wilder.

LOS ANGELES: *Griffith Observatory and Planetarium.* Griffith Park, P. O. Box 9787, Los Feliz Station, Los Angeles 27, Calif., Olympia 1191.

SCHEDULE: Wednesday, Thursday, and Friday at 8:30 p.m.; Saturday and Sunday at 3 and 8:30 p.m.; extra show on Sunday at 4:15 p.m. Zeiss projector. Director, Dinsmore Alter.

NASHVILLE: *Sudekum Planetarium.* Children's Museum, 724 2nd Ave. S., Nashville 10, Tenn., 42-1853.

SCHEDULE: Sunday, 2:45, 3:30, 4:15. Spitz projector. Director, William G. Hassler.

NEW YORK CITY: *Hayden Planetarium.* 81st St. and Central Park West, New York 24, N. Y., Trafalgar 3-1300.

SCHEDULE: Mondays through Fridays, 2, 3:30, and 8:30 p.m.; Saturdays, 11 a.m., 2, 3, 4, 5, and 8:30 p.m.; Sundays and holidays, 2, 3, 4, 5, and 8:30 p.m.; Wednesdays and Fridays, 11 a.m., for school groups. Zeiss projector. Chairman, Robert R. Coles.

PHILADELPHIA: *Fels Planetarium.* Franklin Institute, 20th St. at Benjamin Franklin Parkway, Philadelphia 3, Pa., Locust 4-3600.

SCHEDULE: Tuesdays through Sundays, 3 p.m.; Saturdays, 11 a.m.; Saturdays, Sundays, and holidays, 2 p.m.; Wednesdays, Fridays, and Saturdays, 8:30 p.m. Zeiss projector. Director, I. M. Levitt.

PITTSBURGH: *Buhl Planetarium and Institute of Popular Science.* Federal and West Ohio Sts., Pittsburgh 12, Pa., Fairfax 4300.

SCHEDULE: Mondays through Saturdays, 2:15 and 8:30 p.m.; Sundays and holidays, 2:15, 3:15 and 8:30 p.m. Zeiss projector. Director, Arthur L. Draper.

PORTLAND, ORE.: *Oregon Museum of Science and Industry Planetarium.* 908 N.E. Hassalo St., Portland 12, Ore., East 3807.

SCHEDULE: Saturday, Sunday, and Wednesday, 4:00 p.m.; Tuesday, Thursday, and Friday, 8:00 p.m.; Saturday show for children only, 10:30 a.m. Spitz projector. Director, Stanley H. Shirk.

SAN FRANCISCO: *Morrison Planetarium.* California Academy of Sciences, Golden Gate Park, San Francisco 18, Calif., Bayview 1-5100.

SCHEDULE: Daily (except Monday and Tuesday) at 3:30, 7:30, and 9 p.m.; also at 2 p.m. on weekends and holidays. Academy projector. Manager, George W. Bunton.

SPRINGFIELD, MASS.: *Seymour Planetarium.* Museum of Natural History, Springfield 5, Mass.

SCHEDULE: Tuesdays, Thursdays, and Saturdays at 3 p.m.; Tuesday evenings at 8 p.m.; special star stories for children on Saturdays at 2 p.m. Admission free. Korkosz projector. Director, Frank D. Korkosz.

STAMFORD: *Stamford Museum Planetarium.* Courtland Park, Stamford, Conn.

SCHEDULE: Sunday, 4:00 p.m. Special showings on request. Admission free. Spitz projector. Director, Ernest T. Luhde.

BOOKS AND THE SKY

STARS IN THE MAKING

Cecilia Payne-Gaposchkin. Harvard University Press, Cambridge, 1952. 160 pages and 67 plates. $4.25.

BY ABOUT 1935 a large number of basic fields of astronomy had come to a certain stage of completion. The main features of the internal structure of the stars, both normal and degenerate, had been developed as far as this was possible without detailed knowledge of nuclear physics. The solar and stellar spectra had been analyzed and had given the first over-all picture of the chemical composition of the universe. The Milky Way system had been recognized as a rotating galaxy, and the interstellar clouds in our immediate galactic neighborhood had been outlined by the classical methods of stellar statistics. The first census of galaxies throughout the observable part of the universe had been taken.

In the years immediately following these achievements, the going was hard in astronomy. The tools and techniques used in the preceding decade appeared to permit extensions, but not basic steps ahead.

The first indications of a new wave of advances in astronomy came just before and during the war. Nuclear physics suddenly reached a state where the nuclear transmutations providing the energy source of the stars could be isolated and given in quantitative terms. The first extensive results from the coude spectrograph of the 100-inch telescope at Mount Wilson showed the inexhaustible wealth of data obtainable with such an instrument. The resolution of the nearest elliptical nebulae led to the concept of stellar populations. But only after the end of the war did this new wave reach its present headlong speed.

Today, nuclear physics is turning the theory of the stellar interior from a consideration purely of the present status to the investigation of stellar evolution. Spectroscopists are concentrating on the delicate composition differences between stellar populations, to gain insight into the conditions under which the various star types were born. Observations of emission nebulosities and of the radio radiation from hydrogen clouds give the outlines of the spiral arms in our galaxy. New photoelectric techniques permit color measurements on distant galaxies, possibly giving the first direct evidence of galactic evolution. And with all this, the 200-inch telescope is just putting out its first tentative data.

It is hard to imagine a situation in astronomy more full of promise than the present. It is hard to visualize the development which our picture has undergone during the past few years. It is still harder to keep one's head above the surface of the wave in an effort to maintain an open and objective view. But it is hardest, in the midst of the fast-moving present situation, to write a book, understandable for a layman, on a subject which is one of the central topics of the present astronomical development.

Mrs. Payne-Gaposchkin has had the courage to do just this. It is obvious under the circumstances that a professional reader will find an occasional description or interpretation with which he may not agree. The field is too young for complete objective agreement. But the essential thing is that Mrs. Payne-Gaposchkin has succeeded in describing, in vivid language, the wealth of old and new data bearing on her subject, in reviewing the possible interpretations with persuasive description of her own preferences but honest avoidance of calling speculations facts, and in transmitting to the reader the tension and happy excitement which pervades today's astronomy.

MARTIN SCHWARZSCHILD
Princeton University Observatory

ACROSS THE SPACE FRONTIER

Cornelius Ryan, editor. The Viking Press, Inc., New York, 1952. 147 pages. $3.95.

ACROSS **the Space Frontier** is an expansion of several articles which appeared originally in **Collier's** magazine. It starts with a brief description of the earth's atmosphere by Joseph Kaplan and concludes with astronomer Fred Whipple's conception of an observatory in space, beyond the blindfolding atmosphere. The principal chapter, by Wernher von Braun, tells how a space station, a large, manned, earth satellite, can be established in 10 to 15 years, and a succeeding chapter by Willy Ley describes the space station in some detail. Heinz Haber and Oscar Schachter discuss two tremendous questions: "Can we survive in space?" and "Who owns the Universe?"

Scientific readers should not be disturbed that the conclusions are based in part on existing knowledge and in part on the authors' speculation, since any book on space travel would say little if it did not draw upon both fact and fiction. Unfortunately, the nontechnical reader, for whom the book is written, may not be able to distinguish where the facts end and the fiction begins. And the authors have done little, if anything, to dispel the notion that the entire book rests on a solid, scientific foundation. For example, editor Cornelius Ryan states in the introduction, "The contributors to this book have spelled out the technical specifications for the rocket ship and the space station. And they can detail the design features. All they need now is time — about 10 years — plus money ($4,000,000,000) and authority."

Several of the chapters, particularly those that involve engineering design, make little distinction between what is **possible** and what is **practical.** Among the many engineering problems which the authors assume to be solved or to be amenable to ready solution are the navigation of the shuttle rockets, the recovery of spent rocket stages, the safe return from the orbit of manned vehicles, the maintenance of a livable atmosphere within the space ship, and a source of power for the many complex equipments that must perform the functions necessary for human survival in an alien environment. But there is always the prospect that any

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Insight Into Astronomy

By Leo Mattersdorf
President, Amateur Astronomers Association, Inc., New York City

This book describes in clear terms, for the average person to understand, the solar system, the stars, sun, moon, planets, eclipses, tides, how time is determined, and many other phases of astronomy. It is at once an introduction to astronomy and a basic discourse that will be helpful to young and old alike who thirst for elemental knowledge of the great mysteries of the universe.

It is illustrated with diagrams and photographs, and contains a suggested reading list.

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problem dealing with inanimate matter can be solved eventually.

The most staggering difficulties involve man himself. Through hundreds of thousands of years, a physiology has evolved from acclimation to a given gravitational force, a given atmospheric pressure, a plentiful supply of oxygen, a narrow range of temperature, and an atmospheric shield against damaging radiation. To assume, without extensive tests, that man can tolerate for extended periods of time any wide departure from his normal environment is pure and unfounded speculation. The design of future manned rockets will be influenced most by what we have yet to learn about the needs and limitations of human beings.

Finally, I object strenuously to the contention implied in **Across the Space Frontier** that either we must build a space station to dominate our enemies or they will build one to dominate us. There is not one shred of evidence to prove that a space station can dominate anything, including itself.

One cannot fail to compare **Across the Space Frontier** with another recent book on the same subject, **The Exploration of Space**, by Arthur C. Clarke, chairman of the British Interplanetary Society. In his preface, Clarke states that he has not been afraid to use his imagination where he thought fit. He says, further, that his replies to such questions as "What would a space ship look like?" are based on a most meager foundation of exact knowledge and that such replies will look rather odd in the near future. In short, author Clarke knows the difference between science and fiction, can write a book combining both, and is not ashamed to say he has done so.

Almost without exception, scientists who work with rockets and guided missiles sincerely believe in the future of space travel. But reckless predictions of how much time and money will be required to bring it about do violence to their scientific integrity. Any discussion about space travel should start with the bald statement that, "Today, no one can say how long it will take or how much it will cost."

Despite the objections cited here, **Across the Space Frontier** is a well-written and a provocative book — which bids fair to provide an enjoyable evening for anyone interested in space travel.

MILTON W. ROSEN
Naval Research Laboratory

NEW BOOKS RECEIVED

ADVANCES IN GEOPHYSICS, I, *H. E. Landsberg*, editor, 1952, *Academic Press*. 362 pages. $7.80.

This is the first volume in a proposed series of collected monographs to "summarize, from time to time, the advances that have been made in geophysics." Included in this volume are: Automatic Processing of Geophysical Data, Some New Statistical Techniques in Geophysics, Studies of the General Circulation of the Atmosphere, Exploration of the Upper Atmosphere by Meteoritic Techniques, Unsolved Problems in Physics of the High Atmosphere, Estuarine Hydrography, The Earth's Gravitational Field and Its Exploitation, Aeromagnetic Surveying.

FLYING SAUCERS, *Donald H. Menzel*, 1953, *Harvard University Press*. 319 pages. $4.75.

A Harvard astronomer discusses saucer reports made by day, by night, from the ground, from the air, and on radar. He concludes that "flying saucers" are real phenomena, but that they are generally not what observers think they are. He describes the various types of natural phenomena that are probably involved. There is an appendix on the theory of mirages.

THE SUN, *Herbert S. Zim*, 1953, *Morrow*. 64 pages. $2.00.

A Morrow Junior Book, this one in the field of astronomy joins the author's 11 other science picture books. Profusely illustrated, and with numerous examples of simple experiments young people can do, the book discusses the sun, its position in the solar system and in the universe, and its composition. Sunspots, magnetic storms, solar energy and solar heating, the sun's effect on weather and on plants, are all described briefly and graphically.

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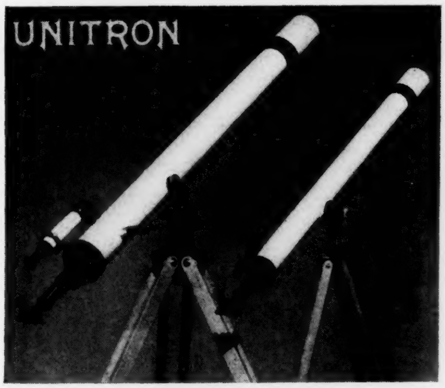

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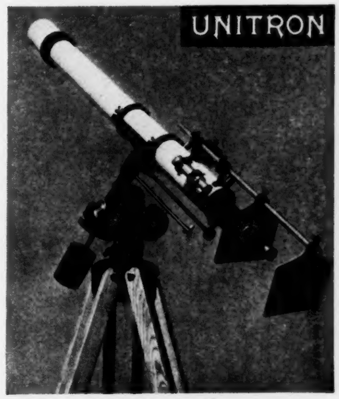

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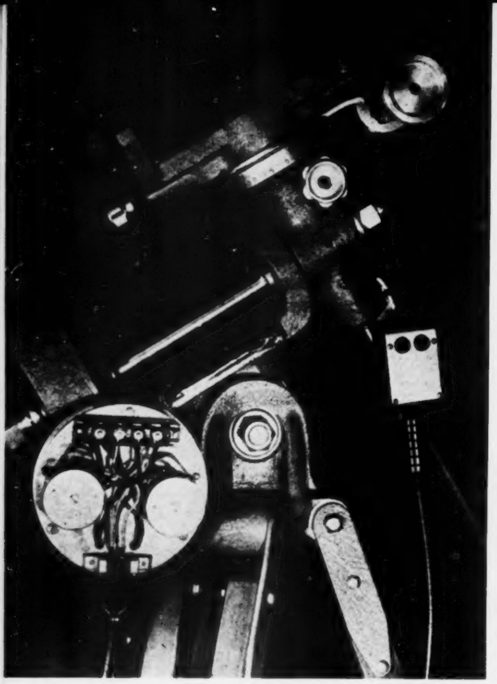
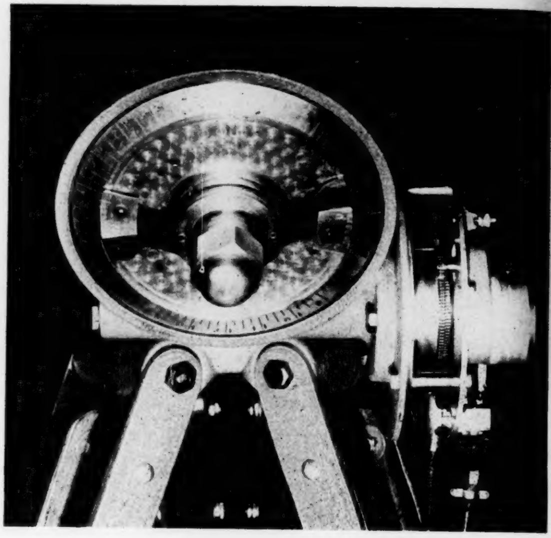


MANY amateur astronomers residing in urban areas have noticed the progressive deterioration of the quality of the night sky due to various man-made causes. The mounting described here is one amateur's answer to city observing conditions. Complete and efficient portability of instruments has been achieved. The portable "observatory" is conveniently carried in the rear seat and trunk of an automobile. Size and weight have been kept to the very minimum consistent with the types of work to be done, including photography.

When transported, the mounting is carried together with the tripod, only the counterweight and the electric punch box that controls the right-ascension slow motion being removed. The weight is 40 pounds, less the counterweight. Within five minutes, the mounting can be set up, oriented, and made ready for operation at the observing site.

The cradle assembly is designed to accommodate any visual or photographic



Left: The portable mounting described in this article, with the cover removed from the motors in the driving mechanism.

Right: The south end of the polar axis, showing the machine-engraved right-ascension circle. The motors and gears of the driving mechanism are seen on the right side of the picture.

All photographs with this article are by courtesy of Ben Kantor.

instrument used by us. Within moments, easy interchange is accomplished by releasing two hand-locking screws. All instruments have two 1/2" steel pins properly positioned and notched for accurate mating with holes bored in the cradle casting. Each instrument has its own counterweight. Transfer from a visual to a photographic program entails no other adjustment than changing the prebalanced instrument and its counterweight. The mounting carries satisfactorily instruments ranging from a camera of 29.4-inch focus to a 6-inch f/13 refractor. The refractor requires a longer-legged tripod.

The drive mechanism has two motors operating through a differential gear train. At a remote observing site, this unit is powered by an ATR 35-watt vibrator power supply operating from the auto's 6-volt battery. The square-wave output of the ATR seems to bring out the best performance in synchronous motors. Even when we have convenient access to domestic power, we seldom use it. Drain on the battery isn't great; however, the car is usually parked facing downhill, just in case!

One motor drives the instrument at a constant sidereal rate. The other exactly doubles the rate for slow-motion corrections. The hand-held punch box contains two corresponding control microswitches. The constant-rate motor is controlled by a push-to-break switch, and the correction motor through a push-to-make microswitch. These are R. W. Cramer permanent-magnet 4-watt timing motors. By comparison, all other motors of this size that we tried were unsatisfactory. In the

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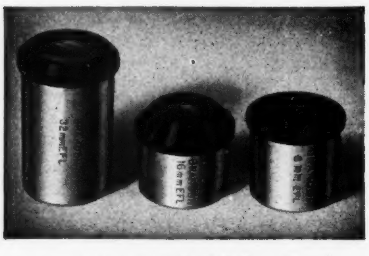

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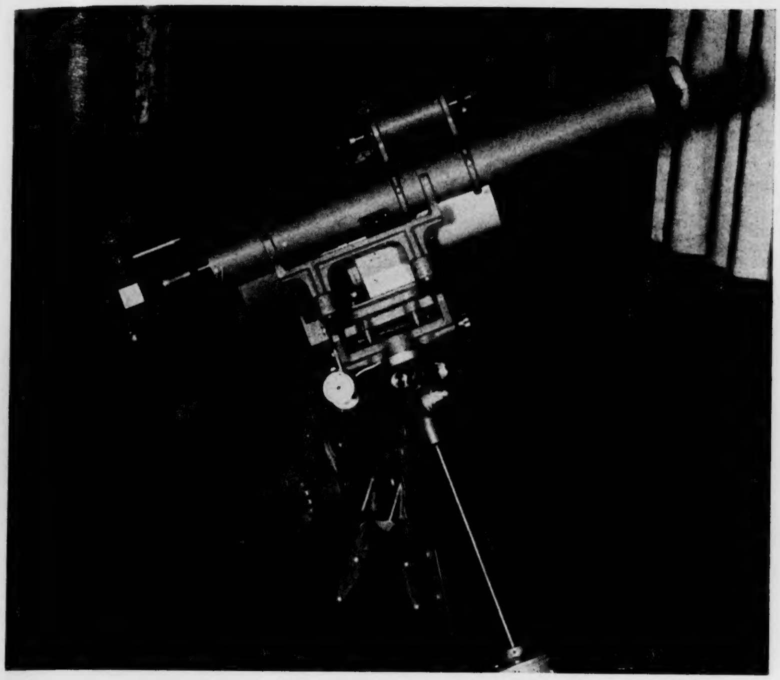

The guide and finder telescopes are easily seen here; the two-mirror Schmidt is on the far side. Note the cap over the motor assembly.

warmth of summer and cold of winter, the little Cramer motors are up to full speed in about half a cycle. This performance permits very "tight" photographic guiding.

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The entire drive is enclosed in a circular case 3¼" deep and 5½" in diameter, which shows in the photograph of the instruments on the mounting. It is completely weatherproofed, and inspection and lubrication are not required oftener than once in five years.

The right-ascension circle, seen in the view of the south end of the polar axis, was engine-divided on a flat ¼" dural plate 8" in diameter. It is of the slip type, which eliminates dealing with time transformations. After a known star is exactly centered in the field, the circle is set with the vernier to the known right ascension of the star. As long as the motor is running, the circle furnishes readings for any observable celestial object. Immediately behind the circle is a weatherproofed clutch. All instruments are so carefully balanced as to make a manual clamp or lock in right ascension completely unnecessary. No slip or irregular performance during very long exposures has ever been noticed.

Declination corrections are accomplished manually through knurled hand knobs located on each end of a 40-thread screw. The declination slow motion is manually controlled, and is of the yoke and saddle type. Manual slow motion remains disengaged and the instrument swings free on the axis until the contrarotating declination brake knobs are tightened.

The entire saddle and slow-motion assembly may be swung 180 degrees, thus placing the slow-motion control knobs in a convenient position for either the refractor or the Newtonian reflector. The declination circle was engine-divided directly on the declination axis casting.

A wide variety of visual and photographic instruments are used with this mounting. The pictures show a photographic combination consisting of a two-

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54 mm (2⅛")	600 mm (23½")	12.50
78 mm (3 1/16")	381 mm (15")	21.00
81 mm (3 3/16")	622 mm (24½")	22.50
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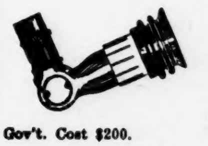

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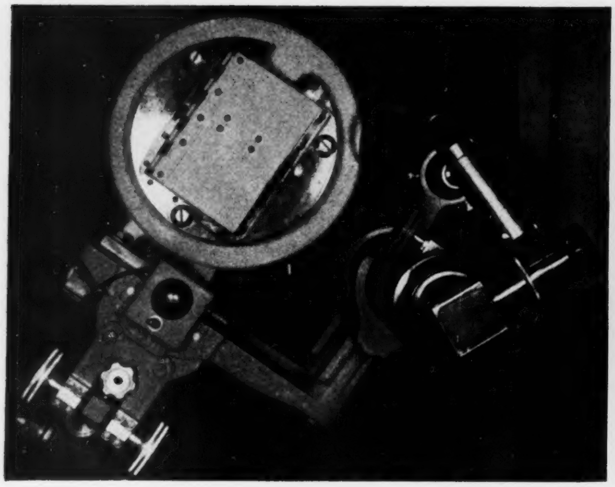

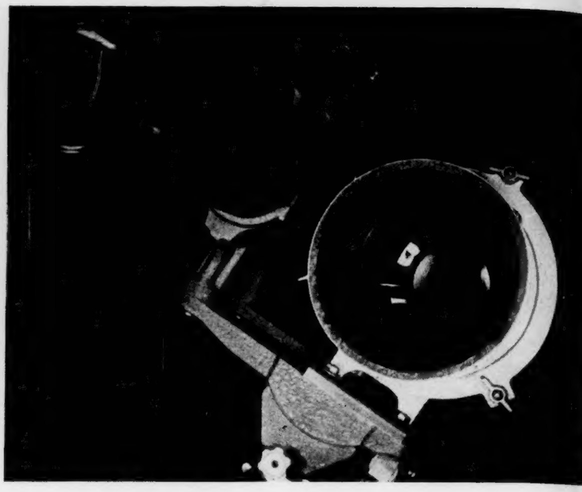

As seen at the left, the two-mirror Schmidt has the photographic plate behind the primary mirror. At the right, note the balanced design that is built into the castings of the parts that support the optical instruments.

mirror Schmidt (with optics by Zeiss reworked by Don Hendrix) and a 3¼-inch refractor for guiding. The plate scale of the Schmidt is about 4.6 minutes of arc per millimeter, and the refractor has a focal length of 41.5″. We borrowed the idea of a projection guiding reticule, which works well, especially when the guide star is of about the 9th magnitude.

Mrs. E. S. Brown, my mother-in-law, does an excellent job of observing and photographing the stars at the age of 74. She has investigated the cluster M41, has observed variables in red and blue light, and worked on the problem of the limiting magnitude of the Schmidt in other regions.

The mounting and accessories were designed and constructed by George Carroll, an active amateur astronomer living in Tujunga, Calif. He is well known among the telescope makers here in southern California.

The writer would be happy to correspond with others interested in systematic observations with instruments of this type.

H. I. SMITH
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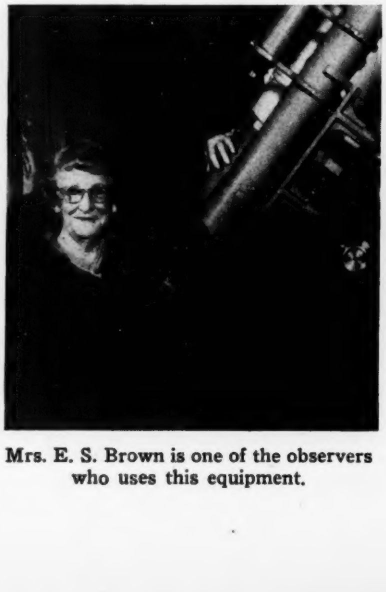

Mrs. E. S. Brown is one of the observers who uses this equipment.

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OBSERVER'S PAGE

Universal time is used unless otherwise noted.

Reports of the Lunar Eclipse in January

Few OBSERVERS along the eastern seaboard were able to observe the moon rising in partial eclipse on January 29th, mostly because clouds and heavy haze obscured the eastern horizon. Later stages were generally observed under more favorable conditions.

Persistent clouds interfered considerably with Toronto amateurs' attempts to view the eclipse, according to Edwin V. Greenwood. Promising conditions at sunset deteriorated rapidly, as a bank of heavy clouds moved in from the north and extended well into the eastern sky. A five-minute glimpse was had shortly after totality began, and about 15 minutes after totality was over the clouds began to break. Scattered clouds added considerable beauty to the last hour of the eclipse.

From Rochester, N. Y., Paul W. Stevens reports that the day was marked by snow flurries and sunshine, the last squall of the day coming at 5:15 and spoiling the view of the initial phases. The moon first emerged from the receding cloudbank at 5:46 p.m., but by the end of totality conditions were excellent. Mr. Stevens did not see any of the predicted occultations, although it was apparent that several took place. Some 30 members of the Astronomy Section of the Rochester Academy of Science observed as a group, using about a dozen instruments.

Mr. Stevens took several series of time-lapse motion pictures, some in color, and one series of still shots with the camera fixed. His group hopes to compare results and compile exposure data in anticipation of getting more and better results at the 1954 lunar eclipses.

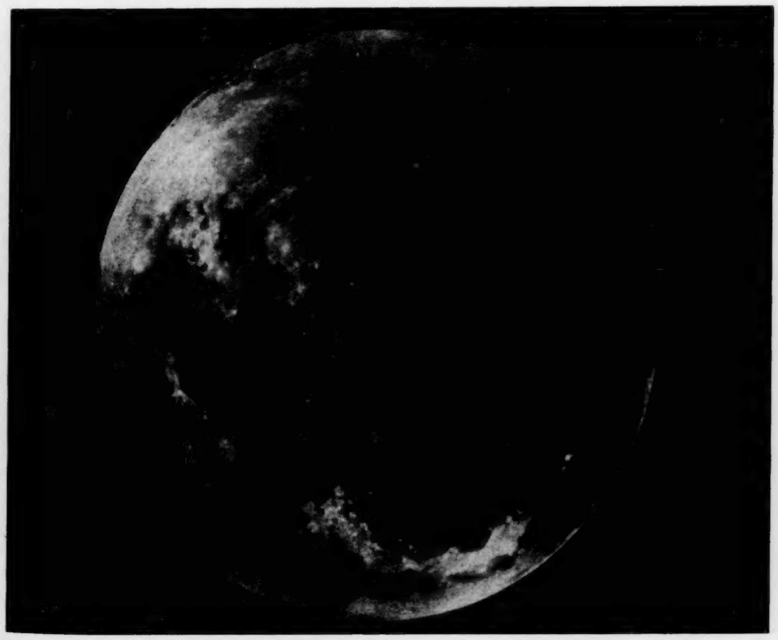
The Rittenhouse Astronomical Society had almost ideal conditions in the Philadelphia area, especially toward the last part of the eclipse. Many photographs were taken, although members tended to underexpose the total phase where cameras were not equatorially mounted and clock-driven. The society members compared their photographic notes and experiences at a post-eclipse meeting.

At the U. S. Naval Observatory in Washington, D. C., Joseph L. Gossner and Arthur A. Hoag employed the 26-inch refractor for a series of photographs. One showing the moon overtaking and occulting X Cancri, a 6th-magnitude variable star, is shown here. This occurred at 6:34 p.m., 13 minutes before mid-totality. A second star on the opposite side of the moon had emerged from occultation a few minutes before the photograph was taken.

To George R. Staples, at Portsmouth, Va., the moon was visible, but not under the best of conditions. After 7 p.m., the moon was darker than during the previous hour, due to high clouds.

Frank B. Dinwiddie, of Nags Head, N. C., writes, "We had a splendid view of the eclipse here on the coast. The lower central portion of the moon was very dark in early totality, but before third contact illumination was complete—a lovely rose on the right side and a pearly gray on the left.

"We generally think the moon rather large to fit inside Orion's head, but during totality it seemed to shrink until it looked too small to make a good fit. This appears to be a brilliance illusion apparently



The moon in total eclipse, with the star X Cancri showing a trail as the moon occults it. The exposure was one minute on Eastman 103a-F emulsion, with no filter. Official U. S. Navy photograph.

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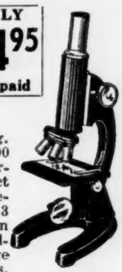

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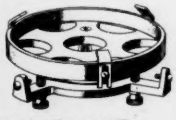

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Greenwich or Universal time	26	00	00
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New York local time	21	04	00
GHA Aries (page 72, Naut. Alm.)	13	31	25
Sid. gain in 26^h x 9.86 sec/hr		4	16
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unrelated to the familiar horizon illusion. We have frequently noted clouds moving past a bright moon with considerable speed, but the same clouds when they actually cross the brilliant disk appear much retarded. However, when thick altostratus dims the disk, this discrepancy disappears, and cloud wisps crossing and near the moon seem to move with uniform speed. This too would seem to be a brilliance illusion. Have others observed this oddity?"

AN OCCULTATION OF CERES

THE ENTIRE eastern half of the United States and Canada will be favored with an occultation of the minor planet Ceres on the evening of April 17th, according to information published in the **Handbook** of the British Astronomical Association from computations by H. M. Nautical Almanac Office. The asteroid is of magnitude 8.5, and it will be hidden by the dark side of the four-day-old moon (illuminated by earthshine). Ceres is the largest of the minor planets, its diameter being generally given as 480 miles; its disappearance behind the moon should be gradual, not instantaneous.

The occultation furnishes those who have never seen Ceres an excellent opportunity to identify the planet by its proximity to the moon. Photoelectric observations may be of value in providing more accurate determinations of the diameter of the asteroid.

It is important to note that the occultation will be visible wherever the sun has set and the sky become dark enough for the asteroid to be seen near the moon in the western sky. Along the East Coast, the occultation occurs two hours after sunset but conditions are less favorable in the Middle West, and the sun is still above the horizon in the Far West. Thus, observers should look for Ceres as soon as twilight begins, using as much telescopic aid as is available. Those far from standard stations may nevertheless make rough predictions of immersion times by noting the trend of these times and their relation to the position angles on the moon. The center of the moon will pass well north of the asteroid for observers in Texas (station F) and other southern states.

Sta.	Immersion	a	b	P
A	8:48.0 EST	—0.8	—0.4	57°
B	8:46.1 EST	—1.0	—0.2	49°
C	8:47.0 EST	—0.7	—0.8	74°
D	8:41.6 EST	—0.9	—0.6	64°
E	7:34.3 CST	—1.0	—1.3	91°
F	7:43.8 CST	—0.7	—2.4	127°

P is the position angle on the moon's limb measured eastward from the north point. Times of immersion are p.m.

The a and b quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computation of fairly accurate times for one's local station (long. Lo, lat. L) within 200 or 300 miles of a standard station (long. LoS, lat. LS). Multiply a by the difference in longitude (Lo — LoS), and multiply b by the difference in latitude (L — LS), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted **time to obtain time at the local station.**

Longitudes and latitudes of standard stations are:

A +72°.5, +42°.5 **E +91°.0, +40°.0**
B +73°.6, +45°.6 **F +98°.0, +31°.0**
C +77°.1, +38°.9 **G +114°.0, +50°.9**
D +79°.4, +43°.7 **H +120°.0, +36°.0**
I +123°.1, +49°.5

MOON PHASES AND DISTANCE

Last quarter	April 7,	4:58
New moon	April 13,	20:09
First quarter	April 21,	0:40
Full moon	April 29,	4:20
Last quarter	May 6,	12:21

	April		Distance	Diameter
Perigee	12,	7^h	224,100 mi.	33′ 08″
Apogee	24,	8^h	251,800 mi.	29′ 30″
	May			
Perigee	10,	5^h	227,200 mi.	32′ 40″

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THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

Mercury, in the morning sky all month, will be at greatest elongation on April 15th, 27° 36′ west of the sun. This will be a poor apparition for observers in northern latitudes for Mercury will be south of the sun, rising less than one hour before it. South of the equator, viewers may see the planet two hours before sunrise.

Venus, although not a spectacular object this month, is on the most interesting section of its travels. Beginning the month as an evening object, setting 1½ hours after the sun at magnitude −3.8, the planet rapidly moves toward the sun. Inferior conjunction occurs on April 13th at 8:00 UT, Venus passing 6° 55′ north of the sun. On the preceding day, the planet will have set 15 minutes after the sun, and the following morning it will rise a half hour before the sun, easily visible to the naked eye. Its crescent shape may be seen all month with small power. After conjunction, Venus may be viewed in a small telescope during the day as an extremely narrow crescent, 59″ in diameter, perhaps with a circle of light around the disk. By the end of the month, the planet will be rising over an hour before the sun, appearing at magnitude −4.0, with nine per cent of the disk illuminated.

Mars, an inconspicuous object of the 2nd magnitude, will set as twilight ends late in April. Moving rapidly eastward, it will pass 1° 9′ north of Jupiter on April 27th.

Jupiter may be viewed for a short time in the western sky after sunset as a bright object of magnitude −1.6. The planet is moving eastward and will be to the south of the Pleiades at the end of the month.

Saturn comes to opposition with the sun on the 14th at a distance of 8.7 astronomical units from the earth. The planet will then appear at magnitude +0.4, located in Virgo and visible all night. The ring system will be a fine object for any telescope, inclined 13°.2 to our line of sight at opposition, the north face visible, with a major diameter of 43″.1; the planet itself will be 17″ in polar diameter.

Uranus may be viewed during evening hours as a 6th-magnitude object moving eastward about 2½° north of Zeta Geminorum. Eastern quadrature with the sun occurs April 4th. The planet's path is shown in the February issue, page 113.

Neptune arrives at opposition on April 12th, at a distance of 29.3 astronomical units from the earth. The planet, in retrograde motion, is about 4° north of Spica in Virgo, and appears of the 8th magnitude. A chart of its path is on page 113 of the February issue.

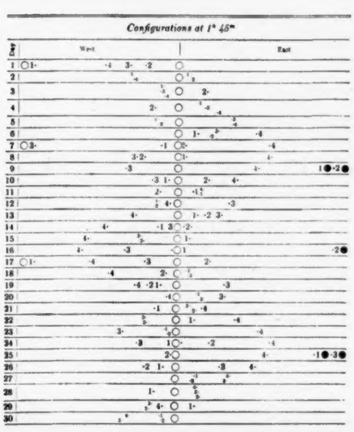
E. O.

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, and the result is your standard time on the day preceding the Greenwich date shown.

JUPITER'S SATELLITES

Jupiter's four bright moons have the positions shown below for the Universal time given. The motion of each satellite is from the dot to the number designating it. Transits of satellites over Jupiter's disk are shown by open circles at the left, eclipses and occultations by black disks at the right. The chart is from the American Ephemeris and Nautical Almanac.



PREDICTIONS OF BRIGHT MINOR PLANET POSITIONS

Iris, 7, 9.6. Apr. 3, 14:55.7 −22-21; 13, 14:48.5 −21-51; 23, 14:39.6 −21-07. May 3, 14:30.0 −20-14; 13, 14:20.6 −19-13; 23, 14:12.4 −18-13.

Nemausa, 51, 9.7. Apr. 23, 16:09.6 −7-15. May 3, 16:03.2 −5-56; 13, 15:54.9 −4-43; 23, 15:45.8 −3-47. June 2, 15:37.3 −3-11; 12, 15:30.3 −2-59.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1953.0) for 0h Universal time. In each case the motion of the asteroid is retrograde. Data supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

SUNSPOT NUMBERS

January 1, 17, 16; **2,** 17, 15; **3,** 21, 13; **4,** 27, 24; **5,** 31, 24; **6,** 45, 35; **7,** 31, 34; **8,** 36, 33; **9,** 48, 44; **10,** 57, 50; **11,** 65, 57; **12,** 60, 59; **13,** 56, 60; **14,** 50, 64; **15,** 49, 60; **16,** 49, 46; **17,** 35, 37; **18,** 26, 30; **19,** 23, 25; **20,** 22, 17; **21,** 14, 14; **22,** 19, 18; **23,** 11, 8; **24,** 9, 8; **25,** 3, 0; **26,** 1, 0; **27,** 0, 0; **28,** 0, 0; **29,** 3, 0; **30,** 0, 0; **31,** 0, 0. Means for January: 26.6 American; 25.5 Zurich.

Daily values of the observed mean relative sunspot numbers are given above. The first are the American numbers computed by Neal J. Heines from Solar Division observations; the second are the Zurich Observatory numbers.

VARIABLE STAR MAXIMA

April 2, T Columbae, 051533, 7.6; 4, RS Librae, 151822, 7.7; 5, R Pegasi, 230110, 7.9; 8, S Pictoris, 0508**48**, 8.0; 12, V Coronae Borealis, 154639, **7.4**; **14,** Omicron Ceti, 021**403**, 3.7; 14, R Cancri, 081112, 6.8; 14, T Aquarii, 204**405**, 7.9; 18, R Aquilae, 190108, 6.3; 22, X Monocerotis, 065**208**, 7.6; 23, R Aurigae, 050953, 7.8. May 1, S Carinae, 100**661**, 5.7.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

APRIL METEORS

The Lyrid meteors may be favorably observed around April 21st after midnight, with the first-quarter moon setting about that time. Expected rates are about 10 per hour. Lyrids appear as swift streaks radiating from a point southwest of Vega.

The sky as seen from latitudes 20° to 40° south, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of July, respectively.

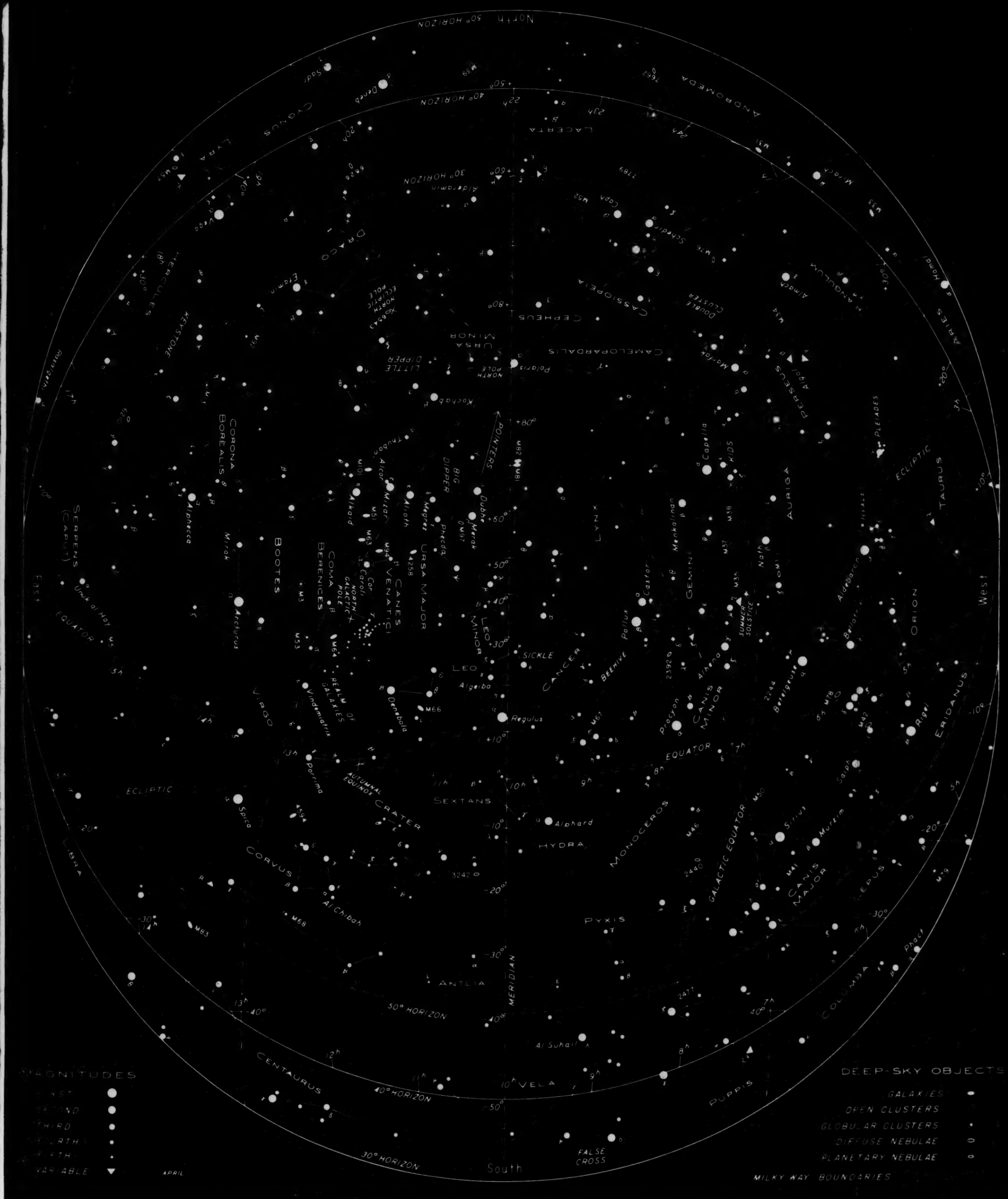
SOUTHERN STARS

BOOTES, Corona Borealis, and Hercules cross the lower part of the northern sky for observers in the Southern Hemisphere on July evenings. A line from Arcturus northeastward through the brightest star in the Northern Crown, Alphecca, can be extended its own length to the Keystone in the constellation of Hercules.

There, slight telescopic aid may be necessary to pick up the great globular cluster, M13, along the western side of the Keystone. This part of the heavens abounds in globular clusters, many of which are marked on the chart.

The Kneeler is seen to advantage from "down under," for he is upright, but farther south and higher in the sky his fellow giant, Ophiuchus, is seen to be upside down.

To the observer at Melbourne, Australia, which is about as far south of the equator as Washington, D. C., is north, Vega must in some ways be more exciting than it is to northerners, who are rather used to its presence in the sky most of the year. On this chart it is shown rising far in the northeast, and in three months it will be setting in the northwest as evening begins, its retinue of faint stars following along behind it.



STARS FOR APRIL

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of April, respectively; also, at 7 p.m. and 6 p.m. on May 7th and 23rd. For other times, add or subtract ½ hour per week. When facing north, hold "North" at the bottom; turn the chart correspondingly for other directions. The projection (stereographic) shows celestial co-ordinates as circles.